Preliminary Assessment of the Sensitivity of West Coast Vancouver Island Marine Species to Climate Change

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2014

Canadian Manuscript Report of Fisheries and Aquatic Sciences 3036

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Fisheries and Aquatic Sciences 3036

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PRELIMARY ASSESSMENT OF THE SENSITIVITY OF WEST COAST VANCOUVER ISLAND MARINE SPECIES TO CLIMATE CHANGE

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Cat. No. Fs97-4/3036E-PDF ISBN 978-1-100-23795-4 ISSN 1488-5387

Correct citation for this publication:

Hunter, K.L., Gillespie, K.M., Brydges, T.M., and Irvine, J.R. 2014. Preliminary assessment of the sensitivity of West Coast Vancouver Island marine species to climate change. Can. Manuscr. Rep. Fish. Aquat. Sci. 3036: v +87 p.

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ABSTRACT

Hunter, K.L., Gillespie, K.M., Brydges, T.M. and Irvine, J.R. 2014. Preliminary assessment of the sensitivity of West Coast Vancouver Island marine species to climate change. Can. Manuscr. Rep. Fish. Aquat. Sci. 3036: v + 87 p.

Establishing priorities associated with maintaining healthy ecosystems and viable fisheries under climate change is a challenging task facing resource managers with limited resources. This study adapted a climate change risk framework developed and used in Australia and applied it to 43 west coast Vancouver Island (WCVI) marine species to assess their sensitivity to climate change. Subsequently, local experts completed the same framework for 6 of these same species, and a short survey was completed as an additional comparison of 14 of the species. Species information assembled from literature for each of 12 attributes was assigned to one of three risk categories. Average risk scores were compiled for each species and compared among species groups, trophic levels and life history strategy types. Based on the literature derived assessment, elasmobranchs were most sensitive to climate change, while flatfishes were the least. The mid-trophic level and 'periodic' life history type were assigned the lowest risk score of their categories. Expert responses were insufficient to evaluate the validity of all the results. However, expert assessments differed from those found by the literature-based assessment in most instances. In the case of Pacific herring, the risk score of the expert-based assessment was much higher. In addition to expert review, a short survey conducted in conjunction with this study revealed that the literature-based assessment did not capture important pieces of local ecological information (i.e. connectivity, seasonality) that appear to be important in assessing species' sensitivity to climate change. Weaknesses with applying the Australian framework to WCVI species were identified; suggestions for improvement included rescaling or redefining attributes that consistently scored low or high. In conclusion, results from literature surveys are a useful starting point when assessing species' sensitivity to climate change. However, when used in isolation they may produce misleading rankings and need to be augmented by expert judgement and specific local information to be confident in the results.

RÉSUMÉ

Hunter, K.L., Gillespie, K.M., Brydges, T.M., and Irvine, J.R. 2014. Preliminary assessment of the sensitivity of West Coast Vancouver Island marine species to climate change. Can. Manuscr. Rep. Fish. Aquat. Sci. 3036: v + 87 p.

L'établissement de priorités concernant le maintien d'écosystèmes sains et de pêches durables malgré les changements climatiques est une tâche difficile pour les gestionnaires des ressources qui ont des moyens limités. Cette étude a adapté un cadre de risque associé au changement climatique utilisé en Australie et l'a appliqué à 43 espèces marines de la côte Ouest de l'île de Vancouver (COIV) pour en évaluer la sensibilité aux changements climatiques. Plus tard, des experts locaux ont adapté ce même cadre à 6 de ces mêmes espèces et on a procédé à une courte étude pour comparer davantage 14 espèces. Des renseignements sur les espèces, provenant de certains documents, et assemblés pour chacun des 12 attributs, ont été attribués à chacune de trois catégories de risque. Des notes moyennes de risque ont été compilées pour chaque espèce et comparées entre les groupes d'espèces, les niveaux trophiques et les stratégies en matière de cycle biologique. Selon l'évaluation qui s'appuyait sur la documentation, les élasmobranches étaient les plus sensibles aux changements climatiques, tandis que les poissons plats l'étaient le moins. Le niveau trophique moyen et le type de cycle biologique « périodique » ont reçu la note la plus basse dans leurs catégories. Les réponses des experts n'ont pas suffi à évaluer la validité de tous les résultats. Toutefois, dans la plupart des cas, les évaluations des experts étaient différentes de celles qui découlaient des évaluations fondées sur la documentation. Pour ce qui est du hareng du Pacifique, l'évaluation du risque donnait un résultat sensiblement plus élevé. En plus de l'examen par les experts, un court examen effectué en même temps que cette étude a révélé que l'évaluation fondée sur la documentation laissait échapper d'importants éléments de renseignements écologiques (c.-à-d. connectivité, caractère saisonnier) qui semblent importants pour l'évaluation de la sensibilité des espèces aux changements climatiques. On a cerné certaines faiblesses en appliquant le cadre australien aux espèces de la COIV, et les suggestions d'amélioration comprenaient le rééchelonnage ou la redéfinition des attributs qui obtenaient systématiquement des notes élevées ou faibles. En conclusion, les résultats des examens de la documentation constituent un point de départ utile lorsqu'on évalue la sensibilité des espèces aux changements climatiques. Toutefois, lorsqu'on les utilise séparément, ils peuvent donner lieu à des constatations qui peuvent induire en erreur et doivent être appuyés par un jugement d'expert et des renseignements locaux spécifiques pour qu'on puisse faire confiance aux résultats.

1.0 INTRODUCTION

Prioritizing risk to fish and fisheries, no matter the driver, is a difficult exercise often lacking appropriate data (Teck et al. 2010). Existing evaluations of the characteristics of marine organisms convey understanding of species sensitivity to environmental forcing or other impacts but lack a framework to compare among species (Winemiller and Rose 1992; King and McFarlane 2003). It has recently come into practice to assess vulnerability of fish and fisheries using risk assessment. One example is the ecosystem risk assessment framework (ERAF) developed in Australia (Hobday et al. 2011) and applied elsewhere (e.g. Holt et al. 2012; DFO 2012).

Using a modified ERAF, Pecl and colleagues in Australia were among the first to assess climate change risks for fish species (Pecl et al. 2011). Their method applies a common framework to a variety of species by associating specific sensitivity attributes of abundance, population distribution and phenology to one of three risk scores. The development of this framework and related assessment required significant investment of expert time and resources (workshops, species synopses etc.). The authors suggested that the method might be applied to other locations to assess species sensitivity to climate change elsewhere.

Ecosystems that support fisheries on the west coast of Canada are a cultural foundation and play an important role in regional economies and food systems where risk to fish and fisheries from climate change is a growing issue and concern (Campbell et al. in press; Halpern et al. 2010; DFO 2013). A climate scenarios based assessment developed to inform likely climate-induced changes to fish and fisheries in the California Current ecosystem (including west coast Vancouver Island, WCVI) demonstrated a need for prioritization of fishery decisions under climate change (King et al. 2011).

To inform fishery-climate change priorities in the Pacific region, we completed a sensitivity assessment using an adaptation of the Pecl et al. (2011) framework as a means of evaluating the climate change sensitivity (i.e. capacity to respond) of 43 marine species from the WCVI. We applied the Pecl et al. (2011) framework by assembling ecological information entirely from published literature. To evaluate the validity of these results, we compared them with results obtained from local species experts using the same framework and a small survey. The resulting species sensitivity rankings are preliminary based on the need for greater consideration of the rankings by local experts.

2.0 METHODS

2.1 STUDY AREA

The study area includes a large portion of the Vancouver Island Shelf (Fig. 1). The continental shelf that extends from the coast is narrow and gently sloping, varying in width from 20-80 km. Its shallow banks, deep basins and troughs are evidence of the effects of glaciation. Offshore, WCVI is an area of variable currents with southerly areas affected by part of the strong and southward flowing California Current in summer, but the remainder of area is characterized by weak and variable currents (Ianson and Flostrand 2010).

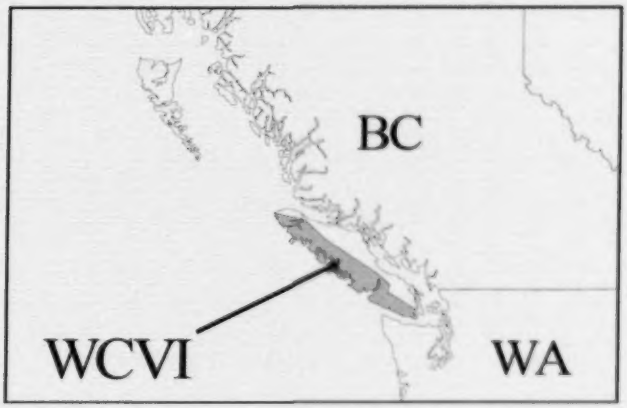


Figure 1. Location of West Coast Vancouver Island (WCVI), British Columbia (BC), Canada.

Productivity throughout this region is high. The marine waters support a neritic plankton community that is strongly influenced by currents and sea-surface conditions (Ianson and Flostrand, 2010). WCVI is the northern limit for several important pelagic species occurring in the California Current ecosystem (King et al., 2011). The area provides rich fishing grounds for benthic fish and invertebrates and the number of species that contribute to fisheries across the region is large. A great deal of variation in life history, distribution and abundance is exhibited among targeted species (Appendix 1). The human population along the coast of WCVI is relatively sparse. There are 13 First Nations communities and a small number of towns supported economically by fishing and summer tourism activities.

2.2 LITERATURE-BASED ASSESSMENT

In total, we examined the sensitivity (i.e. capacity to respond) of 43 marine fish and invertebrates present in WCVI fisheries to climate change. Species included in this assessment were selected by examining DFO fishery catch statistics from WCVI (2000-2012; Statistical areas 21-27, 121-127). Many species we assessed support major fisheries off WCVI. Some species recorded in the data set are not contributors to economically viable fisheries and we did not include those species.

Species were evaluated using pre-determined sensitivity attributes belonging to abundance, distribution and phenology categories (Table 1). Attributes were vetted in technical workshops in Australia to include key features of species that are likely to determine sensitivity to climate change. We determined the risk score (low (1), medium (2) or high (3)) for each attribute (n = 12) using information collected on each species from the literature. Following Pecl et al. (2011), we averaged risk scores of abundance, distribution and phenology categories. The average risk score of each category was summed to arrive at a total risk score and rank (highest – lowest) for each species. We clustered risk scores by species group (elasmobranchs, flatfish, groundfish, invertebrates, pelagics, rockfish), trophic level and life-history strategy type (Winemiller and Rose 1992; King and McFarlane 2003) for further analysis.

Table 1. Attributes, risk categories and criteria used to assess species climate change sensitivity. From Pecl et al. (2011).

Sensitivity attribute		Risk category (sensitivity and capacity to respond to change)		
		High sensitivity (3), low capacity to respond (higher risk)	**Medium (2)**	**Low sensitivity (1), high capacity to respond (lower risk)**
Abundance	Fecundity – egg production	<100 eggs per year	100–20,000 eggs per year	>20,000 eggs per year
	Recruitment period – successful recruitment event that sustains the abundance of the fishery.	Highly episodic recruitment event	Occasional and variable recruitment period	Consistent recruitment events every 1–2 years
	Average age at maturity	>10 years	2–10 years	≤2 years
	Generalist vs. specialist – food and habitat	Reliance on both habitat and prey	Reliance on either habitat or prey	Reliance on neither habitat or prey
Distribution	Capacity for larval dispersal or larval duration – hatching to settlement (benthic species), hatching to yolk sac re-adsorption (pelagic species).	<2 weeks or no larval stage	2–8 weeks	>2 months
	Capacity for adult/juvenile movement – lifetime range post-larval stage.	<10 km	10–1000 km	>1000 km
	Physiological tolerance – latitudinal coverage of adult species as a proxy of environmental tolerance.	<10° latitude	10–20° latitude	>20° latitude
	Spatial availability of unoccupied habitat for most critical life stage – ability to shift distributional range.	No unoccupied habitat; 0 – 2° latitude or longitude	Limited unoccupied habitat; 2–6° latitude or longitude	Substantial unoccupied habitat; >6° latitude or longitude
Phenology	Environmental variable as a phenological cue for spawning or breeding – cues include salinity, temperature, currents, & freshwater flows.	Strong correlation of spawning to environmental variable	Weak correlation of spawning to environmental variable	No apparent correlation of spawning to environmental variable
	Environmental variable as a phenological cue for settlement or metamorphosis	Strong correlation to environmental variable	Weak correlation to environmental variable	No apparent correlation to environmental variable
	Temporal mismatches of life-cycle events – duration of spawning, breeding or moulting season.	Brief duration; <2 months	Wide duration; 2–4 months	Continuous duration; >4 months
	Migration (seasonal and spawning)	Migration is common for the whole population	Migration is common for some of the population	No migration

Following completion of the literature-based assessment, evaluations were circulated to local experts for review. Experts were asked to decide whether the risk score was appropriate according to their knowledge, as well as to comment on references used to generate the original risk score.

3.0 RESULTS

3.1 LITERATURE-BASED ASSESSMENT

Risk scores were assigned based on literature and tabulated for 43 species (Tables 1 and 2; Appendix 1 provides details and literature sources). Average risk scores of abundance (A), distribution (D) and phenology (P) categories were calculated and then summed for each species. Summed average risk scores ranged from 3.75 (Rex sole) to 6.5 (Spotted spiny dogfish) on a scale of 3 to 9 (Table 2). The mean risk score for all species (n = 43) was 5.29 (median of 5.25) or "medium risk". Of the 43 species analysed, 70% received overall risk scores within +/- 0.5 of 5 on a scale of 3 to 9 (Fig. 2). We used the total risk score to rank species (1-43). In general, flatfish and many species of rockfish ranked lowest, while elasmobranchs and a variety of invertebrates, rockfish and pelagic species occupied high and medium risk scores. Some species have the same rank because their risk scores were equal (Fig. 3).

Table 2. Rank of species sensitivity by average total risk score. The average score for each attribute Abundance (A), Distribution (D) and Phenology (P) is out of total of 3 points. The sum of A, D and P is out of total of 9 points. Expert scores are in brackets.

Species	Average risk score Abundance	Average risk score Distribution	Average risk score Phenology	Total of average scores (A+D+P)
Highest Risk				
Spotted spiny dogfish	2.75	1.5	2.25	6.5
Yellowmouth rockfish	2.25	1.75	2.25	6.25
Medium-High Risk				
Pacific oyster	1.5	2	2.5	6
Pacific cod	1.5	1.75	2.75	6
Longnose skate	2.75	2	1.25	6
Widow rockfish	2	1.5	2.5	6
Sharpchin rockfish	2.25	1.5	2.25	6
Vermilion rockfish	2	1.5	2.5	6
Pacific hake	2	1	2.75	5.75
Pacific sea cucumber	2 (1.75)	1.5 (1.5)	2.25 (2.25)	5.75 (5.5)
Redstripe rockfish	2	1.25	2.5	5.75
Medium Risk				
Arrowtooth flounder	1.5	1.25	2.75	5.5
Dungeness crab	1.5	1.5	2.5	5.5
Pacific herring	1.5 (1.75)	1.75(2.25)	2.25(2.5)	5.5 (6.5)
Big skate	2.25	1.75	1.5	5.5
Silvergrey rockfish	2.25	1.25	2	5.5

Canary rockfish	2	1.5	2	5.5
Dover sole	1.75	1.25	2.25	5.25
Lingcod	1.5	1.5	2.25	5.25
Smooth shrimp	1.25	1.75	2.25	5.25
Spot prawn	1.5	1.75	2	5.25
Geoduck	1.5(2)	1.75 (1.75)	2 (2)	5.25 (5.75)
Pacific sardine	1(1.25)	1.75 (1.75)	2.5 (2.5)	5.25 (5.5)
Pacific ocean perch	2	1.5	1.75	5.25
Shortraker rockfish	2.25	1.5	1.5	5.25
Yellowtail rockfish	2	1.25	2	5.25
Walleye pollock	1.5	1.25	2.5	5.25
Albacore tuna	1.75 (1.75)	1.25 (1.25)	2.25 (2.6)	5.25 (5.6)
Medium-Low Risk				
Tanner crab	1.25	2.25	1.5	5
Pacific halibut	1.75	1.25	2	5
Rougheye rockfish	2.25	1.5	1.25	5
Redbanded rockfish	2.25	1.5	1.25	5
Darkblotched rockfish	1.75	1.5	1.75	5
Splitnose rockfish	2.25	1.5	1.25	5
Shortspine thorny head	2.25	1.5	1.25	5
Longspine thornyhead	2	1.5	1.5	5
Red sea urchin	1.25 (1.25)	1.75 (1.75)	2 (2)	5 (5)
Sablefish	1.25	1.5	2	4.75
Lowest Risk				
Bocaccio	2	1.25	1.25	4.5
Petrale sole	1.5	1.25	1.5	4.25
Southern rock sole	1.5	1.25	1.5	4.25
English sole	1.5	1.5	1.25	4.25
Rex sole	1.5	1.25	1	3.75

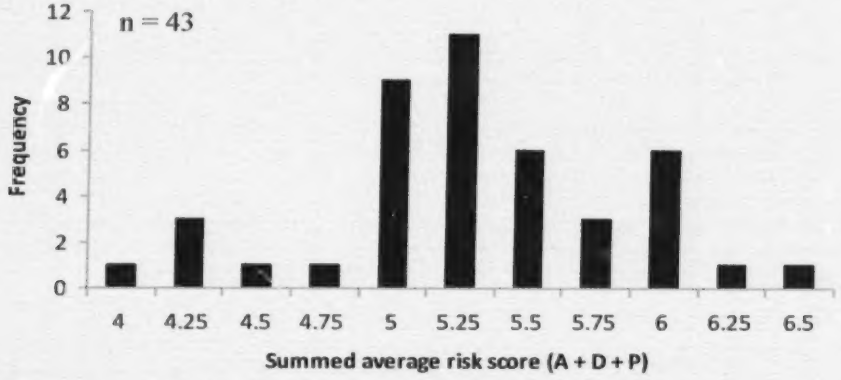


Figure 2. Frequency of total risk score across all species assessments.

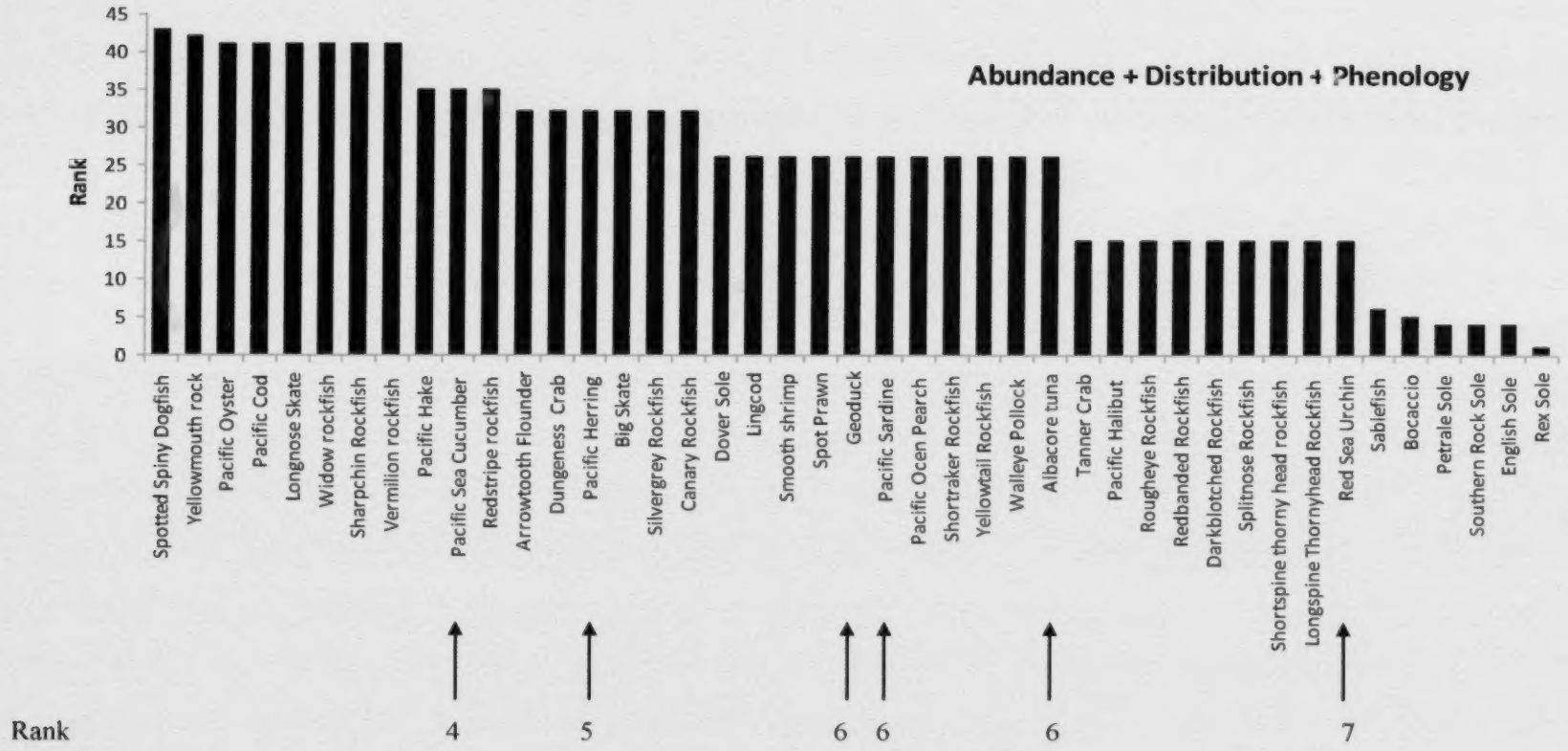


Figure 3. Rank of species (1-43) by total risk score (A+D+P). Labelled ranks identify species also assessed by experts.

RISK SCORES BY CATEGORY

When we examined risk scores by category (abundance, distribution and phenology), average scores ranged from 1 (in distribution) to 2.75 (in both abundance and phenology) out of a possible range of 1 to 3 (Fig. 4). The distribution category received consistently lower scores resulting in lower variation among scores for this category. Of the six species groups and four trophic levels assessed in this analysis, the distribution category was never the leading contributor to higher total risk score. In all cases phenology and abundance consistently received the highest scores and were the greatest contributors to higher risk scores.

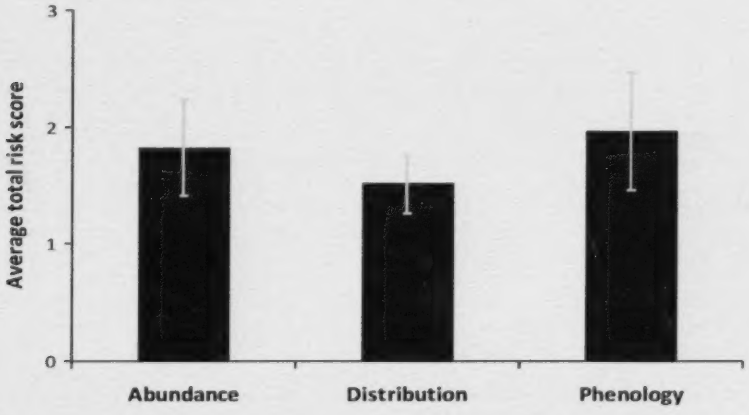


Figure 4. Average risk score by category. A score of 3 indicates high risk; 1 indicates low risk. Vertical bars represent +/-1 standard deviation.

Abundance: The highest ranking species included elasmobranch and rockfish species. These are groups that have lower average productivity as they tend to successfully reproduce infrequently and mature late.

Distribution: The highest ranking species generally displayed low larval dispersal ability and small adult ranges. The middle rank consisted mostly of rockfish which tend to exhibit high site fidelity as adults (and thus low adult range).

Phenology: Species ranks for this attribute were more varied than the abundance or distribution categories. Highly migrant species and those with tendency to inhabit shallower waters ranked higher than those species that use deep water habitat or have low or no migration. This may reflect that deeper water species are less influenced by seasonal environmental conditions for life cycle cues than species with different habitat requirements (e.g. pelagic).

RISK SCORES BY ATTRIBUTE

Examination of the 12 individual criteria revealed trends in risk scores across species (Fig. 5). Most notable were the low risk scores for 'fecundity', 'physiological tolerance' and 'spatial availability of

habitat' criteria. In nearly all cases for these 3 criteria, species were assigned the minimum score of 1, or low risk. Generally, species we assessed have high fecundity, relatively wide physiological tolerance (latitudinal coverage as proxy for adult environmental tolerance), and that the potential for range shift in many populations is high. In contrast, the criteria with higher risk scores included 'adult/juvenile range', 'maturity', 'recruitment' and 'spawning cue'. These criteria suggest species that are late maturing and/or have episodic recruitment events will be vulnerable to the effects of climate change. The high scores for the 'adult/juvenile range' criteria reflect that many species in the study area are in general not highly mobile as adults. As a result of low mobility, environmental cues play an important role in driving spawning events for these species. Changes to environmental cues associated with shifts in ocean climate may cause changes to breeding behaviour and success for some species.

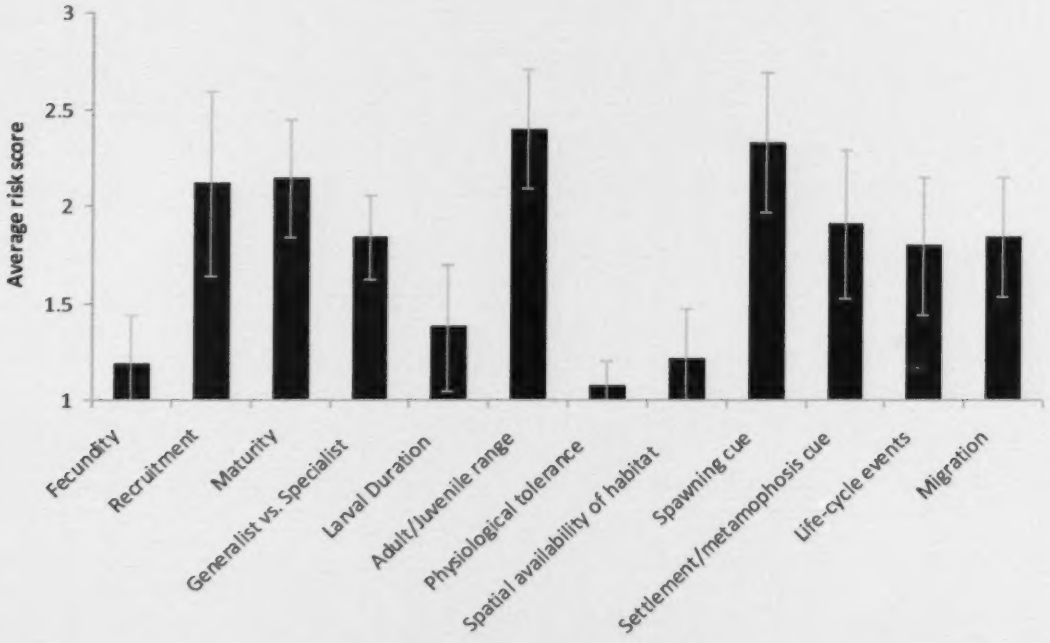


Figure 5. Average risk score by attribute. Each attribute was assessed on a scale of 1-3, with 1 being lowest risk and 3 being highest risk. Vertical bars represent +/-1 standard deviation.

RISK SCORES BY SPECIES GROUP

Species group risk scores suggested that elasmobranchs and flatfish occupy two ends of the risk spectrum while other species groups fall in the middle (Fig.6). The mean risk score for the flatfishes was 4.6 +/- 0.6. Elasmobranchs had a mean of 6.0 +/- 0.5. Pages 10-15 of this report provide synopses of results by species group.

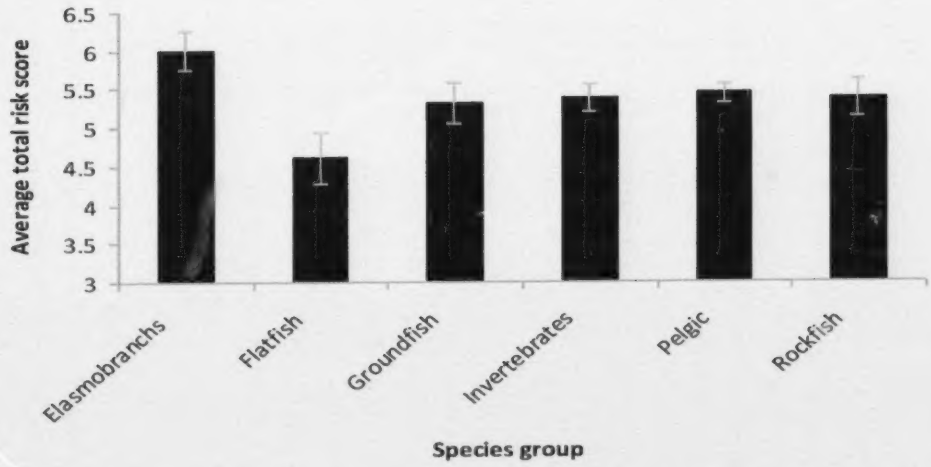


Figure 6. Average risk score by species group. Vertical bars represent +/-1 standard deviation.

Elasmobranchs

Species assessed:

- Big skate (*Raja binoculata*)
- Longnose skate (*Raja rhina*)
- Spotted spiny dogfish (*Squalus suckleyi*)

Summary

Average risk score: 6.0

Risk category: Medium-high

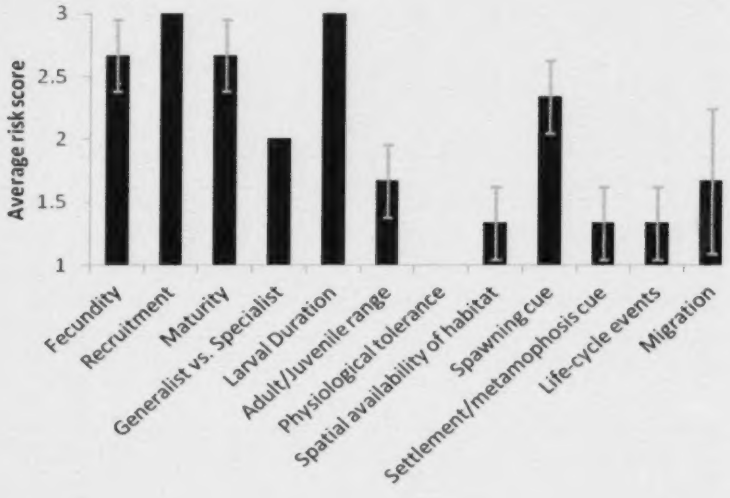
Highest risk score: 6.5 (spotted spiny dogfish)

Category with highest risk: Abundance

Elasmobranchs received the highest average risk score out of all species groups. Risk scores ranged from 5.5 to 6.5. Spotted spiny dogfish received the highest risk score out of all elasmobranchs and out of all species evaluated in the literature-based assessment. Skate species also received relatively high risk scores.

High average risk scores in this group were largely driven by abundance attributes. Fecundity, recruitment, maturity, and generalist/specialist categories all received scores of medium to high risk for all species with recruitment showing no deviation from high risk. These scores are not surprising in light of the life history characteristics of many elasmobranch species. They tend to produce few young at infrequent intervals and reach sexual maturity at a later age.

Distribution risk scores were relatively low with the exception of the larval duration category which was rated as high risk for all three species as all undergo direct development and do not have the opportunity to disperse as larva over long distances. Species in this group have wide latitudinal ranges and physiological temperature tolerance with populations found both to the north and south.



It is unclear if the timing of life cycle events is strongly linked to environmental variables in these species, however, it does appear that many reproductive events can occur year round. Unlike skates, Spotted spiny dogfish undergo seasonal migrations which may provide greater adaptive scope when facing ocean climate change.

Flatfish

Species assessed:

- Arrowtooth flounder (*Atheresthes stomias*)
- Dover sole (*Microstomus pacificus*)
- English sole (*Parophrys vetulus*)
- Petrale sole (*Eopsetta jordani*)
- Pacific halibut (*Hippoglossus stenolepis*)
- Rex sole (*Glyptocephalus zachirus*)
- Southern rock sole (*Lepidopsetta bilineata*)

Summary

Average risk score: 4.6

Risk category: Medium-low

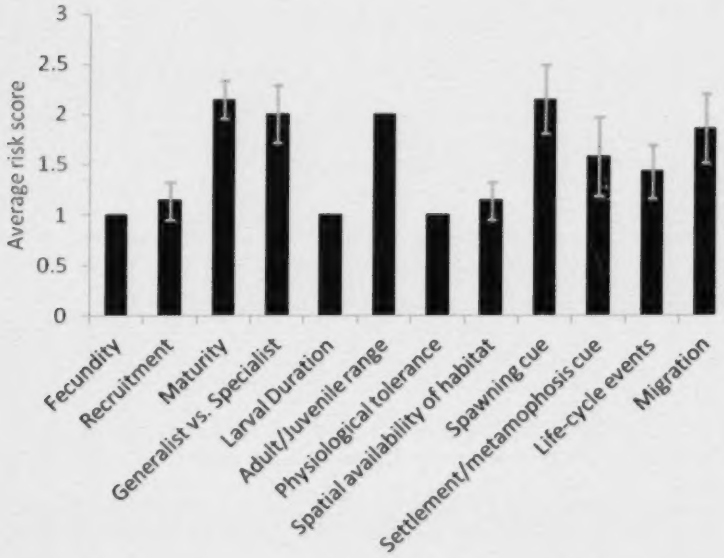
Highest risk score: 5.5 (Arrowtooth flounder)

Category with highest risk: Phenology

The flatfishes received a medium-low average risk score. Individual species scores ranged from 3.75 to 5.5. The Rex sole was assessed the lowest score of all 43 species evaluated in this study. Arrowtooth flounder received the highest risk score (5.5) of this group, driven mainly by phenology attribute scores.

Attributes within the abundance criteria received mixed scores. Fecundity and recruitment were almost entirely assessed as low, however, 'maturity' and' generalist vs. specialist' categories scored higher.

With the exception of 'adult/juvenile range', distribution scores were in the low risk category due to this groups' tendency for long larval duration and physiological tolerance to a range of temperatures. The literature assessment suggested habitat availability is a low risk for this group should changes in ocean conditions force distribution northward.



Phenology attributes drove average risk scores higher for species group. Spawning and larval settlement cues are linked to environmental variables for nearly all species. There is some degree of migration in all species except possibly Rex and English sole.

Groundfish

Species assessed:

- Lingcod (*Ophiodon elongatus*)
- Pacific cod (*Gadus macrocephalus*)
- Sablefish (*Anoplopoma fimbria*)
- Walleye pollock (*Theragra chalcogramma*)

Summary

Average risk score: 5.3

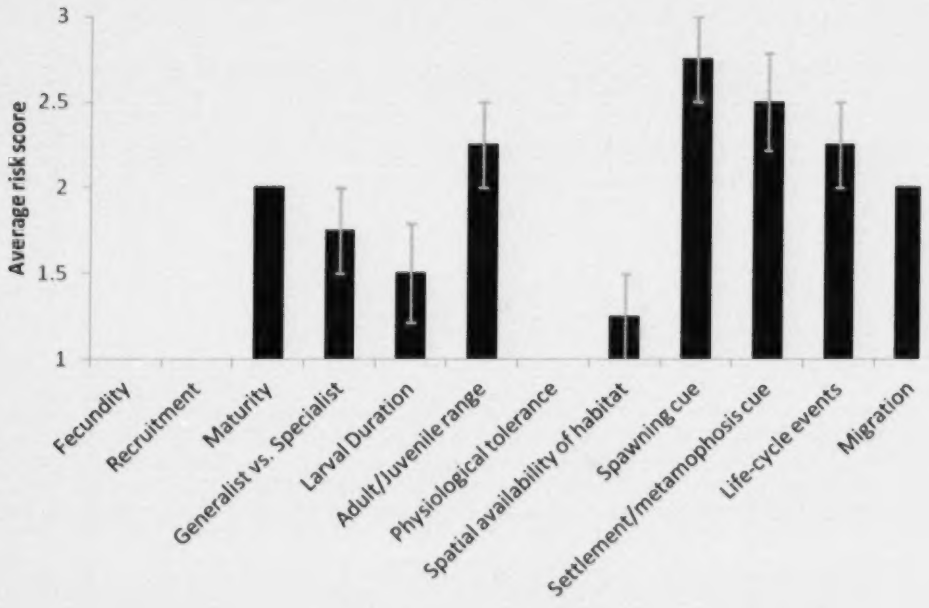
Risk category: Medium

Highest risk score: 6.0 (Pacific cod)

Attribute with highest risk: Phenology

Groundfish were assigned an overall risk rating of 5.3 or medium. Several attributes received low scores masking consistently higher scores in other categories. For example, the low risk scores for all species in 'fecundity', 'recruitment' and 'physiological tolerance' are offset by high phenology risk scores.

In addition to large differences between attributes, there are substantial differences between individual species. Sablefish, for example, had consistently low to medium risk scores for all categories, receiving a total risk score of 4.75. In contrast, Pacific cod scored 1.25 points higher than Sablefish, receiving a total risk score of 6. This was largely due to a suggested link between environmental cues and life cycle events in Pacific cod and lower reliance on these variables for Sablefish as determined by the literature assessment. For all species except Sablefish, phenology scores were much higher than for the abundance and distribution category scores.



Invertebrates

Species assessed:

- Dungeness crab (*Cancer magister*)
- Geoduck (*Panopea abrupta*)
- Pacific oyster (*Crassostrea gigas*)
- Pacific sea cucumber (*Parastichopus californicus*)
- Red sea urchin (*Strongylocentrotus franciscanus*)
- Smooth shrimp (*Pandalus jordani*)
- Spot prawn (*Pandalus platyceros*)
- Tanner crab (*Chionoecetes bairdi*)

Summary

Average risk score: 5.4

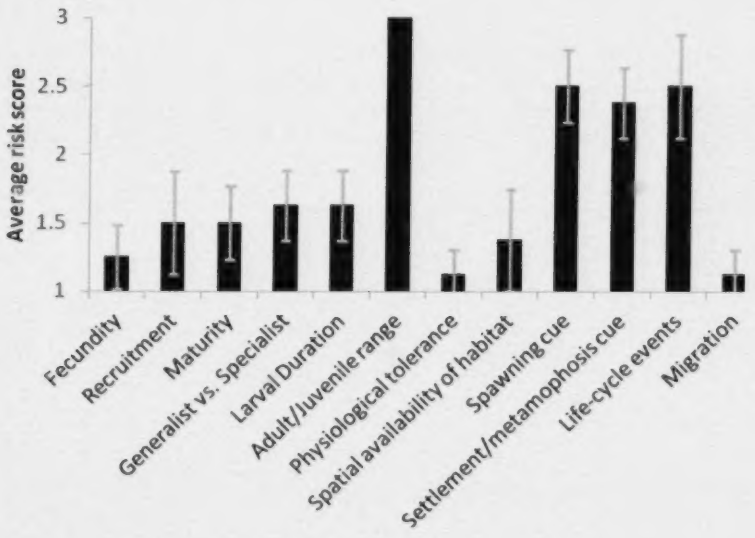
Risk category: Medium

Highest risk score: 6.0 (Pacific oyster)

Attribute with highest risk: Phenology

The invertebrate group encompasses diverse taxa: arthropods, molluscs and echinoderms. Despite taxonomic breadth there was low variability in respective risk rankings for members of this group.

As with many fish species, 'fecundity', 'recruitment', 'physiological tolerance' and 'spatially availability of habitat' elements were scored as low risk. The potential geographic movement of individuals of all species evaluated was very small, resulting in uniformly high risk scores. Invertebrates also appear to have strong environmental cues for life cycle events such as spawning, and larval settlement. This problem is compounded by an inability to move to more desirable habitat due to low or no mobility.



The framework did not include a sensitivity attribute to assess potential impacts of ocean acidification, likely an important factor in determining sensitivity of shellfish. The absence of this type of metric affects the overall interpretation of the results.

Pelagics

Species assessed:

- North Pacifc Albacore tuna (*Thunnus alalunga*)
- Pacific hake (*Merluccius productus*) *semi-pelagic
- Pacific herring (*Clupea pallasii pallasii*)
- Pacific sardine (*Sardinops caerulea*)

Summary

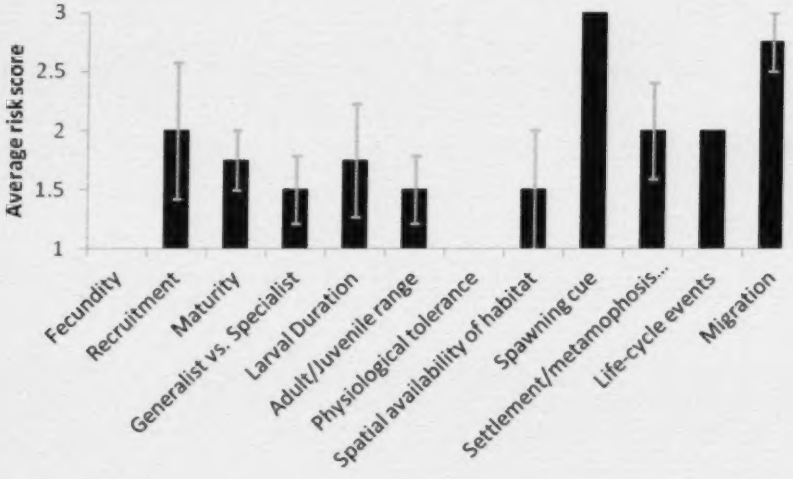
Average risk score: 5.4

Risk category: Medium

Highest risk score: 5.75 (Pacific hake)

Attribute with highest risk: Phenology

This highly migratory group includes both top ocean predators (North Pacific Albacore tuna and Pacific hake) and omnivores (Pacific sardine and Pacific herring). Species in this group rely on multiple habitats and environmental cues for life cycle events. As a result, phenology scores for this group were high. Pacific hake received the highest risk score for this group; mainly due to inconsistent recruitment events and strong links between environmental cues and spawning and larval settling. North Pacific Albacore tuna also have much more infrequent recruitment events and strong links to environmental cues.



Some of these species are more abundant in warmer southern waters. Should ocean temperatures increase on WCVI, conditions may favour increased abundance (distribution shift and/or higher productivity) of some pelagic species.

Rockfish

Species assessed:

- Bocaccio (*Sebastes paucipinis*)
- Canary rockfish (*Sebastes pinniger*)
- Darkblotched rockfish (*Sebastes crameri*)
- Longspine thornyhead rockfish (*Sebastolobus altivelis*)
- Pacific ocean pearch (*Sebastes alutus*)
- Redbanded rockfish (*Sebastes babcocki*)
- Redstripe rockfish (*Sebastes proriger*)
- Rougheye rockfish (*Sebastes aleutianus*)
- Sharpchin rockfish (*Sebastes zacentrus*)
- Shortraker rockfish (*Sebastes borealis*)
- Shortspine thorny head (*Sebastolobus alascanus*)
- Silvergrey rockfish (*Sebastes brevispinis*)
- Splitnose rockfish (*Sebastes diploproa*)
- Vermilion rockfish (*Sebastes miniatus*)
- Widow rockfish (*Sebastes entomelas*)
- Yellowmouth rock (*Sebastes reedi*)
- Yellowtail rockfish (*Sebastes flavidus*)

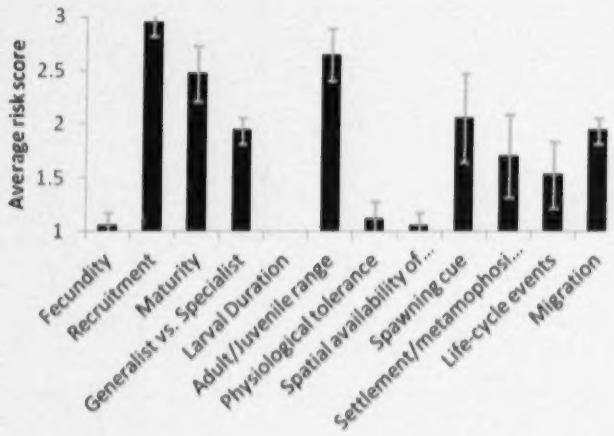
Summary

Average risk score: 5.4

Risk category: Medium

Highest risk score: 6.25 (Yellowmouth rockfish)

Attribute with highest risk: Abundance



Seventeen species of rockfish were assessed. They have diverse life histories which are reflected in the wide range of risk scores (4.5 to 6.25). Unlike other species groups, higher risk scores were predominantly assigned to abundance attributes. High levels of fecundity (and low rick) are contrasted by infrequent recruitment and late age at maturity. In all focal species, larval duration exceeded 8 weeks, placing species into the lowest risk category. The life history of this group of fishes is strongly influenced by the depth at which they live rather than seasonal cues that impact shallow water species. Most rockfish species migrate from shallow to deeper areas with age. Once reaching the depth at which they reach maturity, range is restricted to a small area. High scores for 'adult/juvenile range' reflect a possible sensitivity to climate change linked to their strong habitat affinity.

RISK SCORES BY TROPHIC LEVEL

We obtained trophic level information, except invertebrate species, from Fishbase (fishbase.org). Trophic level of the assessed species varied from 2 – 4.5 indicating large variation of species ecosystem function in the sample. All invertebrate species were assumed to belong to the lowest trophic level (2-2.9). Various fish species were represented by trophic level 3-4 including numerous herbivorous and piscivorous fishes. Trophic level above 4 included highly predatory fishes and all elasmobranchs. Analysis suggested that the average risk score of trophic levels 3-3.4, mainly consisting of flatfish species, was lower than all other trophic level groups (average risk score: 4.8 +/- 0.6 SD). The average risk scores (+/- SD) of the remaining trophic level groups were the same: 2-2.9 = 5.4 +/- 0.3; 3.5-3.9 = 5.4 +/- 0.5, and 4-4.5 = 5.4 +/- 0.6 (Fig. 7).

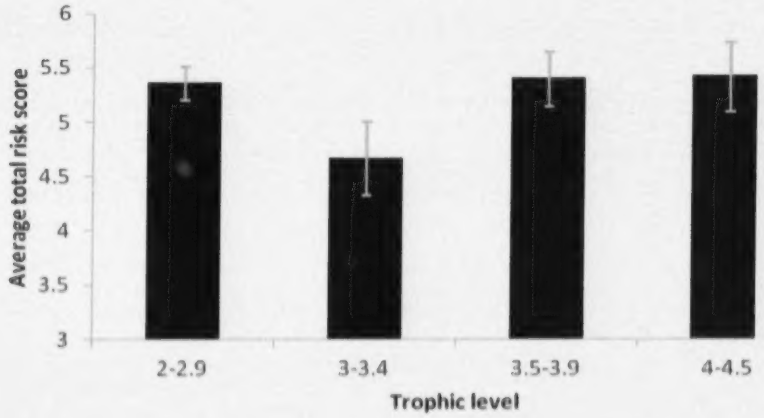


Figure 7. Average risk score by trophic level. Vertical bars represent +/-1 standard deviation.

Trophic Level 2.0 to 2.9

Species assessed:

- Geoduck (*Panopea abrupta*)
- Pacific oyster (*Crassostrea gigas*)
- Pacific sardine (*Sardinops caerulea*)
- Pacific sea cucumber (*Parastichopus californicus*)
- Red sea urchin (*Strongylocentrotus franciscanus*)
- Smooth shrimp (*Pandalus jordani*)
- Spot prawn (*Pandalus platyceros*)

Summary

Average risk score: 5.4

Risk category: Medium

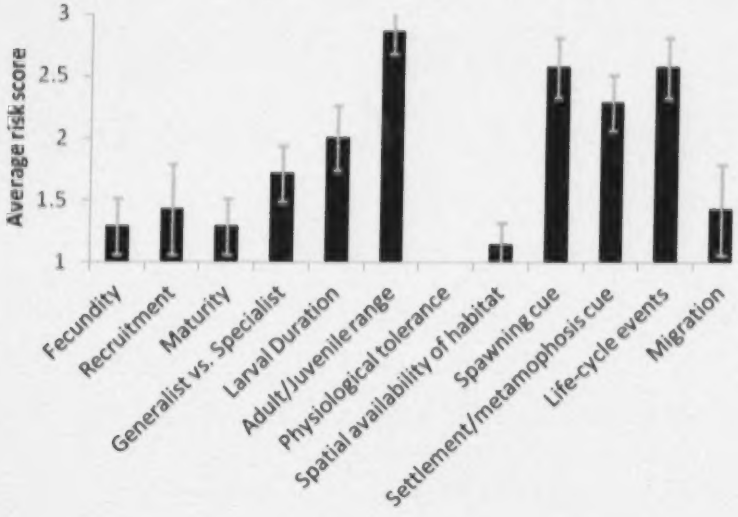
Highest risk score: 6.0 (Pacific oyster)

Attribute with highest risk: Phenology

This trophic level consisted of several herbivorous invertebrate species and a single fish species. Despite wide taxonomic diversity, risk scores were remarkably similar across species. Five of the 7 species were assigned average risk scores between 5.25 and 5.75.

Scores in the abundance category were either low or medium with the exception of the Pacific sea cucumber which scored as high risk in the recruitment category. This group was largely characterized by high fecundity, regular recruitment, and quick maturity. The average value for distribution criteria scores was 1.75. There were highly variable scores among attributes in the distribution category.

Temperature cues for life cycle events are common at this trophic level. As a result, risk scores were high. The impacts of ocean acidification were not assessed in this risk assessment and will likely have a negative impact on this trophic group.



Trophic Level 3.0 to 3.4
Species assessed:

- Dover sole (*Microstomus pacificus*)
- Dungeness crab (*Cancer magister*)
- English sole (*Parophrys vetulus*)
- Longspine thornyhead (*Sebastolobus altivelis*)
- Pacific herring (*Clupea pallasii pallasii*)
- Rex sole (*Glyptocephalus zachirus*)
- Southern rock sole (*Lepidopsetta bilineata*)
- Tanner crab (*Chionoecetes bairdi*)

Summary

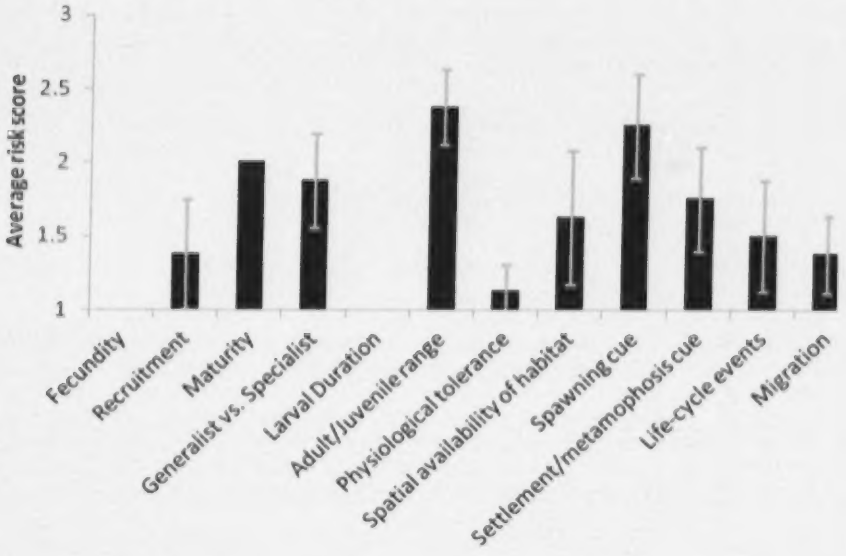
Average risk score: 4.8

Risk category: Medium-low

Highest risk score: 5.5 (Dungeness crab, Pacific herring)

Attribute with highest risk: Abundance, Phenology

This trophic group was largely made up of flatfish, but also includes two invertebrates, one pelagic fish, and one rockfish. All species contributing to this trophic level had uniformly low risk scores in the elements of 'fecundity', 'larval duration' and 'physiological tolerance'. Small adult and juvenile ranges as well as seasonally triggered spawning cues appear to be the greatest risk factor for this trophic level.



Trophic Level 3.5 to 3.9
Species assessed:

- Big skate (*Raja binoculata*)
- Bocaccio (*Sebastes paucipinis*)
- Canary rockfish (*Sebastes pinniger*)
- Darkblotched rockfish (*Sebastes crameri*)
- Longnose skate (*Raja rhina*)
- Pacific ocean pearch (*Sebastes alutus*)
- Redbanded rockfish (*Sebastes babcocki*)
- Redstripe rockfish (*Sebastes proriger*)
- Rougheye rockfish (*Sebastes aleutianus*)
- Sablefish (*Anoplopoma fimria*)
- Sharpchin rockfish (*Sebastes zacentrus*)
- Shortraker rockfish (*Sebastes borealis*)
- Shortspine thornyhead (*Sebastolobus alascanus*)
- Silvergrey rockfish (*Sebastes brevispinis*)
- Splitnose rockfish (*Sebastes diploproa*)
- Vermilion rockfish (*Sebastes miniatus*)
- Walleye pollock (*Theragra chalcogramma*)
- Widow rockfish (*Sebastes entomelas*)
- Yellowmouth rock (*Sebastes reedi*)

Summary

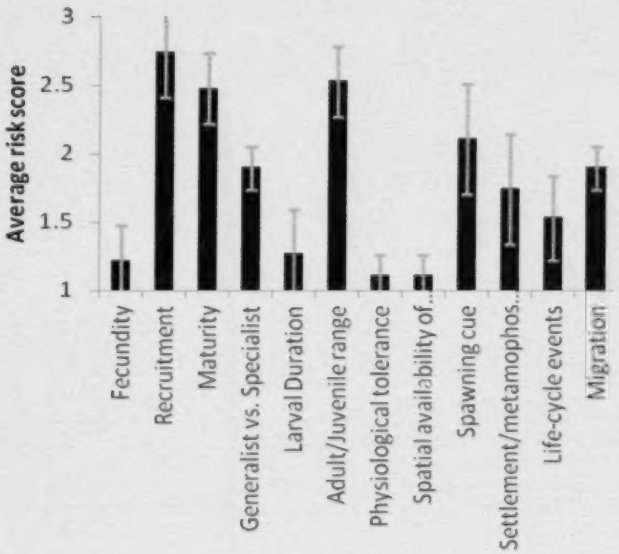
Average risk score: 5.4

Risk category: Medium

Highest risk score: 6.25 (Yellowmouth rockfish)

Attribute with highest risk: Abundance

This group is largely made up of rockfish species. Also contained within this trophic level are two elasmobranchs and Walleye pollock. Abundance attributes received higher risk scores (with the exception of fecundity) than other categories. Higher risk scores for abundance attributes were unique to this trophic level. High variability in risk scores per attribute suggests a wide sensitivity range among species in this trophic level. The wide range of life history traits of rockfishes supports the range in sensitivity of this trophic level.



Trophic Level 4.0 to 4.5

- Albacore tuna (*Thunnus alalunga*)
- Arrowtooth flounder (*Atheresthes stomias*)
- Lingcod (*Ophiodon elongatus*)
- Pacific cod (*Gadus macrocephalus*)
- Pacific hake (*Merluccius productus*)
- Pacific halibut (*Hippoglossus stenolepis*)
- Petrale sole (*Eopsetta jordani*)
- Spotted spiny dogfish (*Squalus sucklevi*)
- Yellowtail rockfish (*Sebastes flavidus*)

Summary

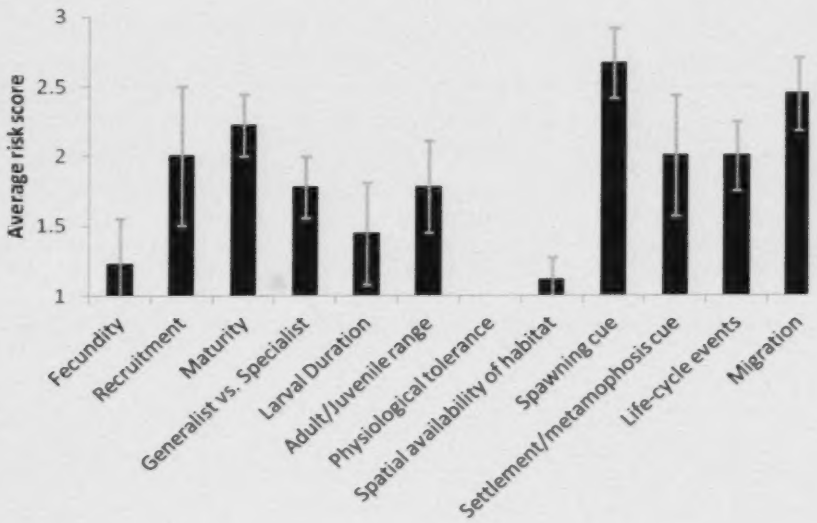
Average risk score: 5.4

Risk category: Medium

Highest risk score: 6.5 (spotted spiny dogfish)

Attribute with highest risk: Phenology

This top trophic species group contains at least one member from each of the five species groups (elasmobranch, flatfish, groundfish, pelagics, and rockfish). Risk scores for phenology attributes were highest for this trophic level driven by a few species highly responsive to changes in sea surface conditions. Distribution risk scores are low in this group driven by highly migratory behaviour of several species. Similar species characteristics that determined high sensitivity in the phenology category (i.e. migration) simultaneously decreased risk scores in the distribution category (adult/juvenile range).



RISK SCORES BY LIFE HISTORY STRATEGY TYPE

Following the work of Winemiller and Rose (1992) and King and McFarlane (2003), we assessed the sensitivity of species life history strategy to climate change using the same Pecl et al. (2011) approach. Among fishes, there are 5 accepted life history strategies, to which 35 of the 43 species we investigated were assigned (no invertebrates; Table 4).

Table 4. Numbers of species per life-history strategy group in this assessment.

Life-history strategy	n
Equilibrium	3
Opportunistic	2
Intermediate	5
Periodic	25
Salmonid	0

Similar to the species group analysis, the equilibrium strategists, represented by elasmobranchs, showed the highest sensitivity. Intermediate strategists, including species such as Pacific cod and Albacore tuna, display mid-range life history traits compared with periodic and opportunistic strategists (King and McFarlane 2003). Their larger size, highly migratory behaviour and longevity may contribute to higher sensitivity to climate change than other strategists. For example, opportunists are short-lived, fast growing, small bodied species with low reproductive investment relative to other species. These life-history traits are widely accepted to be highly adaptive, thereby potentially increasing the capacity of this group of species to respond to climate impacts. Periodic strategists risk scores were the lowest on average. These long-lived, slow growing species occupy shelf or slope benthic habitat and exhibit high fecundity. Relatively low variability in abundance that is linked to longevity and periodically strong recruitment events in these species may contribute to lower sensitivity to climate warming. Concern for the quality of demersal habitats under climate change has been raised repeatedly where depletion of oxygen concentration a depth would likely be detrimental to periodic strategists.

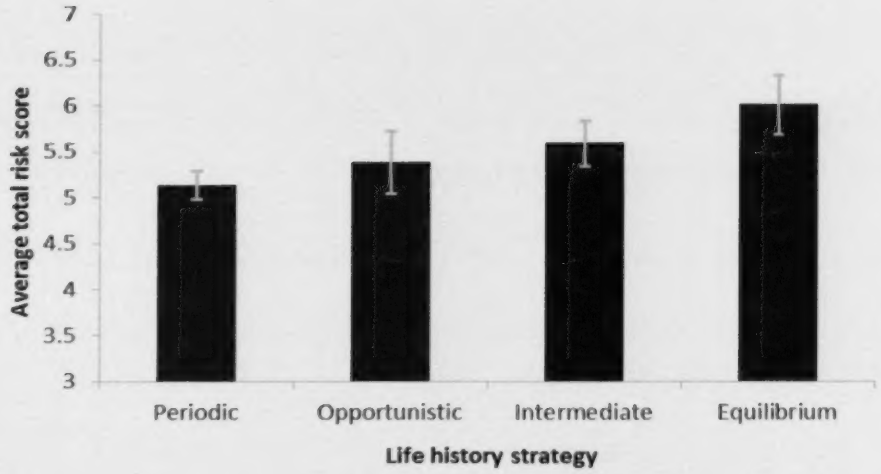


Figure 8. Average risk score by life-history strategy type. Vertical bars represent +/-1 standard deviation.

3.2 EXPERT ASSESSMENT

A sample of the risk scores from the literature-based assessment was reviewed by scientific experts with expertise on fish populations from WCVI. Data assembled from literature was not always specific to populations west coast Vancouver Island. Local species-experts reviewed species tables and the associated risk scores and judged whether the scoring was accurate for specific populations at this location. Six species were assessed by experts (Table 5). Results of the expert assessments compared to literature-based scoring show species ranks rose or fell based on expert judgement (Table 5).

Table 5. Risk scores of literature-based assessment compared to expert judgement.

Species	Literature risk score	Expert risk score	Change	Literature rank	Expert rank
Pacific sea cucumber	5.75	5.5	Decrease	4	5
Pacific herring	5.5	6.5	Increase	5	1
Pacific sardine	5.25	5.5	Increase	6	8
Albacore tuna	5.25	5.6	Increase	6	7
Geoduck	5.25	5.75	Increase	6	4
Red sea urchin	5	5	-	7	7

The majority of the expert assessments were higher than the literature-based assessments. One score decreased (Pacific sea cucumber) and one remained the same (Red sea urchin). Assessments that changed by 0.25 points or more were significant enough to move the species into a different level of sensitivity ranking (Fig. 9). Based on expert judgement, the sensitivity assessment for Pacific herring increased and resulted in it ranking among the most sensitive species in the assessment. Other modifications to risk scores by experts were more moderate, but the risk scale is such that a small change can result in a shift in species rank.

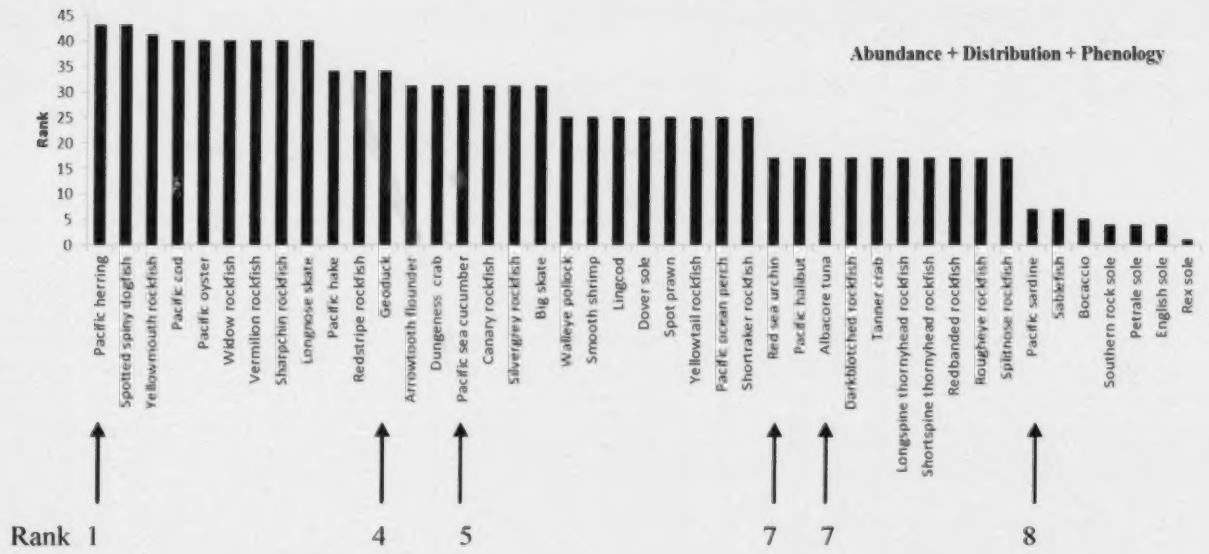


Figure 9. Rank of species (1-43) by total risk score (A+D+P). Labelled ranks identify ranks based on expert assessments.

4.0 DISCUSSION

Biological consequences and risks related to fisheries and climate change in Canada's Pacific region require useful tools to assess and manage risk (DFO 2013). The Pecl et al. (2011) framework was developed to assess climate change vulnerability of Australian marine fish species using a three point scale for 12 risk criteria. Criteria were grouped into three attributes based on three assumptions that influence a species' capacity to respond to climate change, including: (1) more productive species will be more resilient; (2) species with higher dispersal ability will be more resilient; and (3) species that do not rely on seasonal environmental cues or many habitats for key phases of their life cycle will be more resilient. In this assessment, phenology and abundance attributes were commonly scored on average as medium risk or higher. The distribution category was consistently ranked as medium to low risk for the species assessed.

The most sensitive species, as ranked by this framework, are elasmobranchs/equilibrium strategists, while the least sensitive are the flatfishes/periodic strategists. One previous investigation of the impacts of climate change on the California Current ecosystem (off WCVI) used a life history framework to discuss species vulnerability and related ecosystem futures (King et al. 2011). This current study supports the findings of King et al. (2011) which suggested a similar pattern of potential risk to some of the major fisheries species included in this analysis. King et al. (2011) suggested elasmobranchs were at higher risk and some pelagic species (sardine, tuna) at lower risk to climate change given conceptual projections of change to population abundance and expansion. The current study expanded these investigations by assessing invertebrate species sensitivity and capacity to respond to climate change.

The adapted literature-based approach has a number of advantages: 1) species assessments are simple to complete; 2) risk criteria do not require exact values, as ranges are relatively broad; and 3) tables identify gaps in knowledge. However, despite the simplicity of this assessment, there are issues that warrant further consideration when assessing risk scores. The risk score works on a 6 point scale: from 3 to 9. In our analysis, the majority of overall species scores landed within +/-0.5 of 5 on this scale, often making it difficult to interpret finer scale patterns due to the lack of dispersion in scores. Furthermore, during the averaging process, persistently low criterion scores (e.g. fecundity) appear to mask the influence of higher risk scores that may be important in determining sensitivity. It is clear that high variability in scores within and among attributes affect the validity of summarizing the 'risk category' (high, medium, low) across species group or trophic level. Attributes that scored consistently low or consistently high across species may need rescaling or redefining in order to properly capture the variation in WCVI species.

Risk scores of some phenological criteria (i.e. migration) and some distribution criteria (i.e. capacity for juvenile/adult movement) were at times contradictory, depending on species characteristics. For example, Albacore tuna is a highly migratory animal that responds to environmental cues to determine migration behaviour as well as its population distribution. Lifetime range of this species is very large (>1000 km, risk score = 1) and the highly migratory behaviour it displays (risk score = 3) results in this large range. This mismatch leads to highly inaccurate scoring of sensitivity for species with high migration and large ranges.

Turning to the expert review of the literature assessment, while the reviewer sample size was small, it was clear that experts often did not agree with assessments completed using literature-based information only. As further evidence that expert judgement is necessary for this kind of cross-species assessment, results from the related survey showed that important information on the ecology of some of the species is entirely missed by the Pecl et al. (2011) framework (Appendix 2). Because climate change will have impacts on populations locally, results suggest this kind of local expertise is essential to determining specific risks to fish and fisheries at the regional scale.

Based on our assessment of results produced by the framework and resident expert reviews, the Pecl et al. (2011) method may not be appropriate for the ecology for every region, and if used, should be tailored to local environmental and ecological characteristics. This may include adding additional criteria and/or reweighting attribute scoring. For example, in the WCVI region, declining ocean pH is a growing concern for the survival of many species and it may be appropriate to add an additional criterion that takes into account the importance of calcium carbonate on species survival.

The literature-based assessment is a suitable starting point for assessing species sensitivity (capacity to respond) to climate change. However, this tool is not a replacement for human expertise and experience and should be used in combination with expert knowledge and insight.

5.0 ACKNOWLEDGEMENTS

This preliminary assessment of WCVI marine species sensitivity to climate change would not have been possible without the support of colleagues at the Pacific Biological Station, Nanaimo, B.C. Several individuals were helpful at various stages of the process including, Laura Brown, Terry Curran, Linnea Flostrand, Robyn Forrest, Graham Gillespie, Claudia Hand, John Holmes, Jackie King, Rob Kronlund, Ian Perry, Jake Schweigert, Nathan Taylor and Greg Workman. Laura Brown provided a helpful review of an earlier draft of the document. This study was supported by funding from DFO's Aquatic Climate Change and Adaptation Services Program (2012-13).

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7.0 APPENDICES

APPENDIX 7.1. Individual species scores based on literature review. Number indicated in brackets [#] links to literature cited.

Group: Elasmobranchs Species: Big skate (*Raja binoculata*)

Species	*Raja binoculata*	Common Name: Big skate		Trophic level	3.9 s.e. 0.64
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	100-20,000 eggs per year[33]	2	High	>350 egg cases annually in captive specimens. Number of viable cases is unknown. Uniquely, a single *R. binoculata* egg case may contain up to eight embryos.
	Recruitment	Highly episodic recruitment events[69]	3	Low	Unknown time between egg laying events
	Maturity	2-10 years[33]	2	High	5-9 years
	Generalist vs. specialist	Reliance on either habitat or prey[69]	2	Medium	Bottom dwelling, sandy muddy bottoms, feeds on bottom dwelling fish and invertebrates
		Average	2.25		
Distribution	Larval duration	<2 weeks or no larval stage[33]	3	High	Direct development
	Adult/juvenile range	10-1000 km[69]	2	High	Most were captured within ~20km of tagging location (regardless of time at liberation) but some individuals traveled over 1000km
	Physiological tolerance	>20° latitude[39]	1	High	Population Range 61°N - 31°N, 165°W - 117°W; Depth Range 3m-110m
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[39]	1	Low	Populations north and south of WCVI
		Average	1.75		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[33]	2	High	Year round reproduction may be possible, though likely only reproduce 6months of year
	Settlement/metamorphosis cue	Weak correlation to environmental variable[33]	2	Low	Direct development from egg to juvenile. Year-round reproduction may be possible, though likely only reproduce 6 months of year
	Life-cycle events	Continuous duration; >4 months[33]	1	Medium	Year round reproduction may be possible, though likely only reproduce 6 months of year
	Migration	No migration[69]	1	High	
		Average	1.5		
Total Risk Ranking			5.5		

Group: Elasmobranchs Species: Longnose skate (*Raja rhina*)

Species	*Raja rhina*	Common Name: Longnose skate		Trophic level	3.9 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	<100 eggs per year[42]	3	High	Less than 50 eggs per year
	Recruitment	Highly episodic recruitment events[41]	3	Low	Unknown time between egg laying events. Eggs incubate for "several months"
	Maturity	>10 years[42]	3	High	Mature between 11 and 18 years
	Generalist vs. specialist	Reliance on either habitat or prey[41]	2	Medium	Benthic sandy bottom
		Average	2.75		
Distribution	Larval duration	<2 weeks or no larval stage[50]	3	High	Direct Development from egg to juvenile
	Adult/juvenile range	10-1000 km[69]	2	Medium	
	Physiological tolerance	>20° latitude[42]	1	High	Between 61◦N and 28◦N Latitudes
	Spatial availability of habitat	Limited unoccupied habitat; 2-6° latitude or longitude[81]	2	Low	
		Average	2		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[50]	2	Low	Spawning can occur year round but could potentially be seasonal (6 months)
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[41]	1	Low	Eggs develop as yolk is consumed
	Life-cycle events	Continuous duration; >42 months[41]	1	Low	
	Migration	No migration[69]	1	Medium	Similar to big skate. They are not known to be migratory, though individuals may travel long distances.
		Average	1.25		
Total Risk Ranking			6		

Group: Elasmobranchs Species: Spotted spiny dogfish (*Squalus sucklevi*)

Species	*Squalus sucklevi*	Common Name: Spotted spiny dogfish		Trophic level	4.3 s.e. 0.7 (based on S. acanthias)
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	<100 eggs per year[63]	3	High	Average 7.3pups; range 2-16pups
	Recruitment	Highly episodic recruitment events[63]	3	Low	Gestation 23 months. Longest gestation in any vertebrate
	Maturity	>10 years[100]	3	High	35yrs* Reported as S. acanthias, but BC population has been reclassified as separate species since publication
	Generalist vs. specialist	Reliance on either habitat or prey[63]	2	High	Temperature dependant, generalist predator
		Average	2.75		
Distribution	Larval duration	<2 weeks or no larval stage[63]	3	High	
	Adult/juvenile range	>1000 km[17]	1	Medium	*S. sucklevi* was recently separated from *S. acanthias* (2010)- as *S. acathias* is such a wide spread species, it is difficult to determine the exact boundaries of *S. acanthias* and *S.sucklevi* (*S. sucklevi* is generally pacific population)
	Physiological tolerance	>20° latitude[17]	1	Medium	*S. sucklevi* was recently separated from *S. acanthias* (2010)- as *S. acathias* is such a wide spread species, it is difficult to determine the exact boundaries of *S. acanthias* and *S. sucklevi* (*S. sucklevi* is generally pacific population)
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[86]	1	Low	Pacific wide
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[63]	3	High	Spawning occurs between October to February but peaks in December
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[63]	1	High	Gestation period is relatively constant
	Life-cycle events	Wide duration; 2-4 months[63]	2	Medium	Gestation period is relatively constant and spawning can take place over several months
	Migration	Migration is common for the whole population[100]	3	Medium	West Coast has resident populations in Strait of Georgia and trans-pacific migratory populations- though confusion with *S. acanthias* may be a result.
		Average	2.25		
Total Risk Ranking			6.5		

Group: Flatfish Species: Arrowtooth flounder (*Atheresthes stomias*)

Species	*Atheresthes stomias*	Common Name: Arrowtooth flounder		Trophic level	4.3 s.e. 0.7
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[12]	1	High	250,000 to 2,400,000
	Recruitment	Consistent recruitment events every 1-2 years[111]	1	Medium	
	Maturity	2-10 years[105]	2	High	Age of 50% maturity is 7.6 years
	Generalist vs. specialist	Reliance on either habitat or prey[121]	2	Medium	Reliance on walleye pollock
		Average	1.5		
Distribution	Larval duration	>2 months[12]	1	High	~145 days
	Adult/juvenile range	10-1000 km[111]	2	Low	
	Physiological tolerance	>20° latitude[111]	1	Medium	Species is present from California to Gulf of Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[123]	1	High	Species is present from California to Gulf of Alaska
		Average	1.25		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[12]	3	Medium	Spawning occurs in the winter months
	Settlement/metamorphosis cue	Strong correlation to environmental variable[12]	3	Medium	
	Life-cycle events	Wide duration; 2-4 months[12]	2	High	
	Migration	Migration is common for the whole population[111]	3	Low	Migration to deeper water in winter
		Average	2.75		
Total Risk Ranking			5.5		

Group: Flatfish Species: Dover sole (*Microstomus pacificus*)

Species	*Microstomus pacificus*	Common Name: Dover sole		Trophic level	3.3 s.e. 0.4
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[59]	1	High	37,000 ova to 265,800
	Recruitment	Consistent recruitment events every 1-2 years[59]	1	Low	yearly spawning
	Maturity	2-10 years[59]	2	High	Maturity from 5-7, at 11 years of age all are mature. Highest maturity in northern regions (e.g. WCVI)
	Generalist vs. specialist	Reliance on both habitat and prey[59]	3	High	Dover sole spawn at specific sites in offshore waters- feed exclusively on benthic inverts
		Average	1.75		
Distribution	Larval duration	>2 months[59]	1	High	Take up benthic life after 1 year
	Adult/juvenile range	10-1000 km[59]	2	High	Tagging studies show approximately 19 km dispersal
	Physiological tolerance	>20° latitude[59]	1	High	Baja California to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[59]	1	Medium	Distribution continues both North and South of WCVI
		Average	1.25		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[59]	3	Medium	November through March. Peak January to February
	Settlement/metamorphosis cue	Weak correlation to environmental variable[59]	2	Medium	Settle one year later (January to February)
	Life-cycle events	Wide duration; 2-4 months[59]	2	High	
	Migration	Migration is common for some of the population[59]	2	High	Dover sole adults undergo annual bathymetric migrations- no North/South migration
		Average	2.25		
Total Risk Ranking			5.25		

Group: Flatfish Species: English sole (*Parophrys vetulus*)

Species	*Parophrys vetulus*	Common Name: English sole		Trophic level	3.4 s.e. 0.46
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[69]	1	High	913 000
	Recruitment	Consistent recruitment events every 1-2 years[37]	1	Low	Yearly spawning but ocean conditions greatly affect yearclass success
	Maturity	2-10 years[37]	2	High	4 years
	Generalist vs. specialist	Reliance on either habitat or prey[37]	2	High	Sandy substrates- general benthic predator
		Average	1.5		
Distribution	Larval duration	>2 months[37]	1	High	6-10 weeks
	Adult/juvenile range	10-1000 km[37]	2	High	See similar species
	Physiological tolerance	>37° latitude[37]	1	High	California to Alaska
	Spatial availability of habitat	Limited unoccupied habitat; 2-6° latitude or longitude[37]	2	High	Populations north and south, though WCVI is nearing the northern extent of Commercial population
		Average	1.5		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[37]	2	Medium	Spawning September to March
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[37]	1	High	Dependent of currents delivering to nursery
	Life-cycle events	Continuous duration; >4 months[37]	1		
	Migration	No migration[37]	1	High	Minimal migration
		Average	1.25		
Total Risk Ranking			4.25		

Group: Flatfish Species: Pacific halibut (*Hippoglossus stenolepis*)

Species	*Hippoglossus stenolepis*	Common Name: Pacific halibut		Trophic level	4.1 s.e. 0.7
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[69]	1	High	2 250 000 eggs
	Recruitment	Occasional and variable recruitment period[21]	2	High	Yearly spawning BUT Regime shifts over 20 years have large effects on recruitment
	Maturity	>10 years[21]	3	High	Age at 50% mature 11-12 years
	Generalist vs. specialist	Reliance on neither habitat or prey[21]	1	High	Generalist predator
		Average	1.75		
Distribution	Larval duration	>2 months[21]	1	High	6 months as larvae
	Adult/juvenile range	10-1000 km[21]	2	High	By age 8 movement is minimal except for migration for spawning
	Physiological tolerance	>20° latitude[21]	1	High	Mid-California - Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[21]	1	High	Significant populations north and south of WCVI
		Average	1.25		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[106]	2	Medium	Yearly but due to habitat depth, unlikely correlated to environmental variability
	Settlement/metamorphosis cue	Weak correlation to environmental variable[106]	2	Medium	Yearly but due to habitat depth, unlikely correlated to environmental variability
	Life-cycle events	Wide duration; 2-4 months[106]	2	High	Spawning occurs over 4-5 months
	Migration	Migration is common for some of the population[21]	2	High	Mature adults migrate to spawn
		Average	2		
Total Risk Ranking			5		

Group: Flatfish Species: Petrale sole (*Eopsetta jordani*)

Species	*Eopsetta jordani*	Common Name: Petrale sole		Trophic level	4.1 s.e. 0.65
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[69]	1	High	800 000
	Recruitment	Consistent recruitment events every 1-2 years[8]	1	Low	Yearly spawning
	Maturity	2-10 years[1]	2	High	Closely related species mature in 3-9 years (50% at 5 years)
	Generalist vs. specialist	Reliance on either habitat or prey[44]	2	High	Sandy sediments
		Average	1.5		
Distribution	Larval duration	>2 months[91]	1	High	Larval period 6 months
	Adult/juvenile range	10-1000 km[59]	2	High	Similar species have moderate movement
	Physiological tolerance	>20° latitude[91]	1	High	Bering sea to California
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[91]	1	High	Populations north and south of WCVI
		Average	1.25		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[91]	2	Medium	Winter spawn November-April (6 months)
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[91]	1	Medium	Larval period approximately 6 months- dependant on habitat availability
	Life-cycle events	Continuous duration; >4 months[91]	1	High	
	Migration	Migration is common for some of the population[91]	2	High	Migrate to specific spawning sites
		Average	1.5		
Total Risk Ranking			4.25		

Group: Flatfish Species: Rex sole (*Glyptocephalus zachirus*)

Species	*Glyptocephalus zachirus*	Common Name: Rex sole		Trophic level	3.2 s.e. 0.4
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[9]	1	High	34 191-23 8144 eggs
	Recruitment	Consistent recruitment events every 1-2 years[1]	1	High	Recruit to adult population within a year
	Maturity	2-10 years[1]	2	High	Estimated 50% mature in 5.1 years (100% by 9 years)
	Generalist vs. specialist	Reliance on either habitat or prey[1]	2	High	Sandy bottoms/ variety of prey
		Average	1.5		
Distribution	Larval duration	>2 months[9]	1	High	About 1 year
	Adult/juvenile range	10-1000 km[8]	2	Medium	See other sole
	Physiological tolerance	>20° latitude[1]	1	High	Bering sea to Baja California
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[1]	1	High	4 separate stocks. BC stock is managed separately
		Average	1.25		
Phenology	Spawning cue	No apparent correlation of spawning to environmental variable[1]	1	High	Spawning season at least 8 Months - October-May
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[9]	1	High	Settlement at 40mm if Pelagic larvae is in shallow waters, it will delay metamorphosis until it reaches appropriate habitats
	Life-cycle events	Continuous duration; >4 months[1]	1	High	Long spawning and full year larvae
	Migration	No migration[9]	1	High	No specific spawning sites
		Average	1		
Total Risk Ranking			3.75		

Group: Flatfish Species: Southern rock sole (*Lepidopsetta bilineata*)

Species	*Lepidopsetta bilineata*	Common Name: Southern rock sole		Trophic level	3.2 s.e. 0.4
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[69]	1	High	950 000
	Recruitment	Consistent recruitment events every 1-2 years[59]	1	High	Yearly spawning
	Maturity	2-10 years[59]	2	High	Mature from 5-11 years (most by 7 years)
	Generalist vs. specialist	Reliance on either habitat or prey[59]	2	High	Specific spawning sites; feed on benthic invertebrates and fish
		Average	1.5		
Distribution	Larval duration	>2 months[59]	1	High	Metamorphosis in 1 year
	Adult/juvenile range	10-1000 km[59]	2	High	Similar species dispersal approximately 19km
	Physiological tolerance	>20° latitude[59]	1	High	Baja California to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[59]	1	High	Populations north and south of WCVI
		Average	1.25		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[59]	2	High	Winter spawning (5 months)
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[59]	1	High	Settlement based on availability of habitat (depth of larvae)
	Life-cycle events	Continuous duration; >4 months[59]	1	High	Many months
	Migration	Migration is common for some of the population[59]	2	High	Specific spawning sites
		Average	1.5		
Total Risk Ranking			4.25		

Group: Groundfish Species: Lingcod (*Ophiodon elongatus*)

Species	*Ophiodon elongatus*	Common Name: Lingcod		Trophic level	4.3 s.e. 0.72
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[119]	1	High	100,000-500,000
	Recruitment	Consistent recruitment events every 1-2 years[119]	1	Low	Breed yearly in January and February
	Maturity	2-10 years[119]	2	High	2 years for males 3 years for female
	Generalist vs. specialist	Reliance on either habitat or prey[119]	2	High	Rocky reef
		Average	1.5		
Distribution	Larval duration	>2 months[61]	1	High	February to June
	Adult/juvenile range	<10 km[79]	3	Medium	Localized (less than 1km)
	Physiological tolerance	>20° latitude[119]	1	High	Baja California to Aleutian peninsula
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[119]	1	High	Population north and south of WCVI
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[119]	3	Medium	
	Settlement/metamorphosis cue	Weak correlation to environmental variable[61]	2	Medium	Temperature/dispersal mediated
	Life-cycle events	Wide duration; 2-4 months[61]	2	Medium	Short spawning period, but longer larval period
	Migration	Migration is common for some of the population[79]	2	High	Females migrate to shallow spawning grounds
		Average	2.25		
Total Risk Ranking			5.25		

Group: Groundfish Species: Pacific cod (*Gadus macrocephalus*)

Species	*Gadus macrocephalus*	Common Name: Pacific cod		Trophic level	4.01 s.e. 0.7
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[69]	1	High	148 250 eggs
	Recruitment	Consistent recruitment events every 1-2 years[46]	1	High	
	Maturity	2-10 years[46]	2	High	Mature in 2 years
	Generalist vs. specialist	Reliance on either habitat or prey[46]	2	Medium	Generalist predator, range between 63°N - 31°N
		Average	1.5		
Distribution	Larval duration	2-8 weeks[46]	2	Medium	Larvae hatch about 3-4mm and metamorphose 20-25mm. Hatching takes between 10- and 20 days (based on average WCVI temp in March/April). Yolk consumed in 10 days.
	Adult/juvenile range	10-1000 km[46]	2	High	WCVI population separate from other BC/ Eastern Pacific Populations
	Physiological tolerance	>20° latitude[46]	1	Medium	
	Spatial availability of habitat	Limited unoccupied habitat; 2-6° latitude or longitude[46]	2	Low	
		Average	1.75		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[46]	3	High	Spawning occurs Feb -March. Particularly in March
	Settlement/metamorphosis cue	Strong correlation to environmental variable[46]	3	Low	Development is temperature dependant
	Life-cycle events	Brief duration; <2 months[46]	3	Low	Spawning occurs March. Development temperature dependant
	Migration	Migration is common for some of the population[46]	2	High	Not considered migratory, but individuals have been found to travel over 1000km. Northern populations migrate from deep to shallow water to spawn
		Average	2.75		
Total Risk Ranking			6		

Group: Groundfish Species: Sablefish (*Anoplopoma fimria*)

Species	*Anoplopoma fimria*	Common Name: Sablefish		Trophic level	3.8 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[69]	1	High	679 500 eggs
	Recruitment	Consistent recruitment events every 1-2 years[78]	1	High	Yearly spawning January-April with peak in February
	Maturity	2-10 years[78]	2	High	Mean ages at maturity were4.8 for males and 5.1 for females indicating that 50% of males and females spawned for the first time at age 5
	Generalist vs. specialist	Reliance on neither habitat or prey[78]	1	High	Generalist predator/groundfish
		Average	1.25		
Distribution	Larval duration	2-8 weeks[78]	2	Medium	"several weeks"
	Adult/juvenile range	10-1000 km[78]	2	High	Of 127 tags recovered, 90% were taken within 200 km and 81% within 100 km of the tagging location
	Physiological tolerance	>20° latitude[67]	1	High	Baja California to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[67]	1	High	Populations occur significantly north and south of WCVI
		Average	1.5		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[78]	2	High	Life in deep waters reduces impact of seasons (see below)
	Settlement/metamorphosis cue	Weak correlation to environmental variable[78]	2	High	Therefore, spawning, embryological development, hatching, and early post hatching life history stages take place below the relatively more dynamic upper waters, at temperatures and salinities generally below 6°C
	Life-cycle events	Wide duration; 2-4 months[78]	2	High	
	Migration	Migration is common for some of the population[78]	2	High	Spawning occurs on continental slope- fish not on slope migrate to spawn
		Average	2		
Total Risk Ranking			4.75		

Group: Groundfish Species: Walleye pollock (*Theragra chalcogramma*)

Species	*Theragra chalcogramma*	Common Name: Walleye pollock		Trophic level	3.5 s.e. 0.5
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[117]	1	High	Produce 60,000 to 400,000 pelagic eggs
	Recruitment	Consistent recruitment events every 1-2 years[32]	1	Medium	
	Maturity	2-10 years[117]	2	High	Recruit to the fishery at age 4
	Generalist vs. specialist	Reliance on either habitat or prey[9]	2	High	Generalist predator. Selective spawning grounds
		Average	1.5		
Distribution	Larval duration	>2 months[16]	1	High	108 days
	Adult/juvenile range	10-1000 km[117]	2	High	Wide range with local isolated populations
	Physiological tolerance	>20° latitude[32]	1	High	Central California to St. Lawrence Island in the northern Bering Sea and to the southern Sea of Japan
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[32]	1	High	Continuous populations north and south of WCVI
		Average	1.25		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[32]	3	Medium	Spawning occurs in first 6 months of the year but most during 2 or 3 weeks in some populations (temperature dependant)
	Settlement/metamorphosis cue	Strong correlation to environmental variable[16]	3	Medium	Temperature dependant spawning and development
	Life-cycle events	Wide duration; 2–4 months[16]	2	High	Seasonal variation
	Migration	Migration is common for some of the population[115]	2	Medium	Adults form local populations, population mixing occurs when eggs and larvae drift between populations
		Average	2.5		
Total Risk Ranking			5.25		

Group: Invertebrates Species: Dungeness crab (*Metacarcinus magister)*

Species	*Metacarcinus magister*	Common Name: Dungeness crab		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[38]	1	High	Up to 500 000 eggs
	Recruitment	Occasional and variable recruitment period[38]	2	High	Yearly spawning with varying recruitment success
	Maturity	2-10 years[122]	2	High	10 moults (2 years) from the time of settlement before they reach sexual maturity
	Generalist vs. specialist	Reliance on neither habitat or prey[122]	1	High	Detritivore, sand silt muddy bottoms
		Average	1.5		
Distribution	Larval duration	>2 months[80]	1	High	130-150 days
	Adult/juvenile range	<10 km[38]	3	High	
	Physiological tolerance	>20° latitude[122]	1	High	Mexico to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[122]	1	High	Populations north and south of WCVI
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[80]	3	High	Mating May-June. Eggs layed September-October
	Settlement/metamorphosis cue	Strong correlation to environmental variable[80]	3	High	Ontogeny requires approximately 130- 150days. Settling determined by environmental cues (currents etc.)
	Life-cycle events	Brief duration; <2 months[80]	3	Medium	Spawning occurs over short period
	Migration	No migration[80]	1	Medium	Migration is limited, distribution due to larval drift
		Average	2.5		
Total Risk Ranking			5.5		

Group: Invertebrates Species: Geoduck (*Panopea abrupta*)

Species	*Panopea abrupta*	Common Name: Geoduck		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[52]	1	High	
	Recruitment	Highly episodic recruitment events [53]	3	High	Population age structure is dominated by a few strong cohorts
	Maturity	2-10 years[52]	2	High	By age 3 all are mature but not all have spawned
	Generalist vs. specialist	Reliance on either habitat or prey[54]	2	High	Filter feeder- requires soft substrate for burrowing
		Average	2		
Distribution	Larval duration	2-8 weeks[54]	2	High	16-47 days
	Adult/juvenile range	<10 km[54]	3	High	Immobile
	Physiological tolerance	>20° latitude[54]	1	High	California to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[54]	1	High	Populations north and south of WCVI
		Average	1.75		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[54]	2	Medium	Summer spawning
	Settlement/metamorphosis cue	Weak correlation to environmental variable[54]	2	Medium	16-47 days;possible temperature dependence
	Life-cycle events	Brief duration; <2 months[54]	3	High	Summer spawn and short larval period
	Migration	No migration[54]	1	High	Immobile
		Average	2		
Total Risk Ranking			5.75		

Group: Invertebrates Species: Pacific oyster (*Crassostrea gigas*)

Species	*Crassostrea gigas*	Common Name: Pacific oyster		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[90]	1	High	50,000,000- 100,000,000 eggs
	Recruitment	Occasional and variable recruitment period[90]	2	High	Annual spawning but only between Pendrell Sound and Pipestem inlet, when temps reach 19.5°C
	Maturity	≤2 years[90]	1	High	Maturity reached in first year
	Generalist vs. specialist	Reliance on either habitat or prey[90]	2	High	Generalist filter feeder. Dependant on suitable substrate
		Average	1.5		
Distribution	Larval duration	2-8 weeks[90]	2	High	Three weeks (between Mid-July and Mid-August)
	Adult/juvenile range	<10 km[90]	3	High	Stationary
	Physiological tolerance	>20° latitude[90]	1	High	Morrow Bay California to Northern BC
	Spatial availability of habitat	Limited unoccupied habitat; 2-6° latitude or longitude[90]	2	High	WCVI is approaching the Northern boundary- but there are significant populations further south
		Average	2		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[90]	3	High	Temperature reaches 19.5°C
	Settlement/metamorphosis cue	Strong correlation to environmental variable[90]	3	High	Development highly temperature dependant. Settlement based on finding suitable substrate
	Life-cycle events	Brief duration; <2 months[90]	3	High	Very short development/spawning
	Migration	No migration[90]	1	High	Stationary
		Average	2.5		
Total Risk Ranking			6		

Group: Invertebrates Species: Pacific sea cucumber (*Parastichopus californicus*)

Species	*Parastichopus californicus*	Common Name: Pacific sea cucumber		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[27]	1	Medium	Cucumbers (in general) can release around 130,000 eggs
	Recruitment	Highly episodic recruitment events[27]	3	High	Age of recruitment can be up to 4 years
	Maturity	2-10 years[27]	2	High	Age can only be determined for first 3 years
	Generalist vs. specialist	Reliance on neither habitat or prey[27]	1	High	Epibenthic deposit-feeder common on rock and sometimes shell bottoms.
		Average	1.75		
Distribution	Larval duration	>2 months[107]	1	High	13 weeks after fertilization larvae settle
	Adult/juvenile range	<10 km[27]	3	Medium	Can move up to 3.9 metres in a day
	Physiological tolerance	>20° latitude[27]	1	High	Gulf of Alaska to Cedros Island, west of Lower California; intertidal to 249 m.
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[27]	1	High	Significant populations North and South
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[82]	3	High	May- triggered by periods of sunny days
	Settlement/metamorphosis cue	Weak correlation to environmental variable[107]	2	Medium	Free-swimming larva feeds on plankton for 35 to 52 days before settling to the bottom
	Life-cycle events	Wide duration; 2-4 months[82]	2	Medium	
	Migration	Migration is common for some of the population[107]	2	High	Seasonal migration to different depths
		Average	2.25		
Total Risk Ranking			5.5		

Group: Invertebrates Species: Spot prawn (*Pandalus platyceros*)

Species	*Pandalus platyceros*	Common Name: Spot prawn		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	100-20,000 eggs per year [65]	2	Medium	2 628 to 4 669 larvae
	Recruitment	Consistent recruitment events every 1-2 years[108]	1	High	Prawn collected from BC fisheries showed annual recruits
	Maturity	≤2 years[3]	1	High	Reach maturity in 2 years, other studies (Marlave and Roth 1995) suggest some reach maturity as early as 1 year, and others (Sundra 1986) suggest up to 4 years - as post-juveniles become male and convert to female as they age (as in females mature at age 4)
	Generalist vs. specialist	Reliance on either habitat or prey[77]	2	High	Generalist scavengers, inhabiting rocky substrate
		Average	1.5		
Distribution	Larval duration	2-8 weeks[65]	2	Medium	26 to 35 days
	Adult/juvenile range	<10 km[3]	3	High	Tags averaged 143 days at liberty, all recovered within 1.7km (max liberty 1562 days)
	Physiological tolerance	>20° latitude[77]	1	High	Aleutian Islands, Alaska to San Diego, California
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[77]	1	High	Populations north and south of WCVI
		Average	1.75		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[108]	2	Medium	Spawn in fall and incubate until late winter
	Settlement/metamorphosis cue	Weak correlation to environmental variable[62]	2	Medium	Settlement in May and June, no known specific cue
	Life-cycle events	Brief duration; <2 months[77]	3	Medium	Spawning over brief period, hatching over brief period, and settlement over brief period
	Migration	No migration[3]	1	High	Limited spatial movement
		Average	2		
Total Risk Ranking			5.25		

Group: Invertebrates Species: Red sea urchin (*Strongylocentrotus franciscanus*)

Species	*Strongylocentrotus franciscanus*	Common Name: Red sea urchin		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[64]	1	High	Several million eggs
	Recruitment	Consistent recruitment events every 1-2 years[64]	1	High	Annual spawning. In British Columbia it occurs spring to fall
	Maturity	≤2 years	1	High	Maturity 1-2 years after settlement (spawning by two years of age)
	Generalist vs. specialist	Reliance on either habitat or prey[64]	2	High	
		Average	1.25		
Distribution	Larval duration	2-8 weeks[64]	2	High	Larvae settle in 6-8 weeks
	Adult/juvenile range	<10 km[563]	3	High	Average 7.5cm/day and aggregate groups remain relatively stationary
	Physiological tolerance	>20° latitude[64]	1	High	Baja California to Kodiak Island, Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[64]	1	High	Populations north and south of WCVI
		Average	1.75		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[64]	2	High	Spawning based on food availability
	Settlement/metamorphosis cue	Strong correlation to environmental variable[64]	3	High	Selective settlement near adults but larval development is determined by environment
	Life-cycle events	Wide duration; 2-4 months[64]	2	High	Long reproductive season, based on food availability
	Migration	No migration[64]	1	High	No migration
		Average	2		
Total Risk Ranking			5		

Group: Invertebrates Species: Smooth pink shrimp (*Pandalus jordani*)

Species	*Pandalus jordani*	Common Name: Smooth pink shrimp		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	100-20,000 eggs per year[99]	2	High	600-3000 eggs
	Recruitment	Consistent recruitment events every 1-2 years[99]	1	Medium	Yearly spawning
	Maturity	≤2 years[99]	1	High	Reach maturity within one year (other Pandalus- reproduce by year 2)
	Generalist vs. specialist	Reliance on neither habitat or prey[94]	1	High	Prefer sandy sediment, but inhabit wide habitat types and filter/selective feed
		Average	1.25		
Distribution	Larval duration	2-8 weeks[99]	2	High	10 days to 40 days (usually between 15-20)
	Adult/juvenile range	<10 km[94]	3	High	Very localized populations
	Physiological tolerance	>20° latitude[98]	1	High	Unalaska (53°N) to San Diego (32°N)
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[98]	1	High	Populations well north and south of WCVI
		Average	1.75		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[99]	3	Medium	Seasonal spawning (2-3weeks) in late Feb/early March
	Settlement/metamorphosis cue	Weak correlation to environmental variable[99]	2	Medium	temperature dependant though 2-8weeks
	Life-cycle events	Brief duration; <2 months[99]	3	High	
	Migration	No migration[94]	1	High	No migration
		Average	2.25		
Total Risk Ranking			5.25		

Group: Invertebrates Species: Tanner crab (*Chionoecetes bairdi*)

Species	*Chionoecetes bairdi*	Common Name: Tanner crab		Trophic level	
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[89]	1	High	200, 000 eggs per year
	Recruitment	Consistent recruitment events every 1-2 years[89]	1	High	Eggs hatch March-May and females starts producing new eggs in June
	Maturity	2-10 years[31]	2	High	Maturity in six years
	Generalist vs. specialist	Reliance on neither habitat or prey[62]	1	High	Feed on benthic prey- other crabs, benthic fish
		Average	1.25		
Distribution	Larval duration	>2 months[97]	1	Medium	Two Zoeae stages (30 days each) and one Megalops stage (30 days) before settling (total 90 days)
	Adult/juvenile range	<10 km[103]	3	Medium	No Migration
	Physiological tolerance	10-20° latitude[103]	2	Low	Bering Sea and Gulf of Alaska
	Spatial availability of habitat	No unoccupied habitat; 0-2° latitude or longitude	3	Low	WCVI is potentially the most southern population?
		Average	2.25		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[97]	2	Medium	Hold eggs for nearly a year (June-April)
	Settlement/metamorphosis cue	Weak correlation to environmental variable[97]	2	High	Yearly, but no clear environmental cue
	Life-cycle events	Continuous duration; >4 months[89]	1	High	Long egg development (as eggs attached to female pleopods)
	Migration	No migration[103]	1	Medium	No migration
		Average	1.5		
Total Risk Ranking			5		

Group: Pelagics Species: Albacore tuna (*Thunnus alalunga*)

Species	*Thunnus alalunga*	Common Name: Albacore tuna		Trophic level	4.3 s.e. 0.7
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[18, 88]	1	High	0.2-1.7 million eggs per batch; Note that these figures are specific to the WPO. Estimates of fecundity for central Pacific near Hawaii (Otsu and Uchida 1959) span a larger range (0.2-2.6 million), but are old and based on indirect methods, hence uncertainty is high.
	Recruitment	Highly episodic recruitment events[18, 88, 112]	3	High	Spawning period probably extended from March to September; Peak spawning occurs Mar-Apr in WPO (Chen et al. 2010) and probably June-Aug in CPO (Ueyanagi 1957; Otsu and Uchida 1959). At least 1 recruitment event per year, possibly 2 but CPO studies are based on indirect methods and lack the verification of spawning activity reported in recent WPO study (Chen et al. 2010). 1+ recruitment events per year
	Maturity	2-10 years[18, 112]	2	High	50% mature at age- 5, all mature age-6 and older; NOTE: spatial variation in maturity is unknown as maturity schedule is based on fish from the WPO only.
	Generalist vs. specialist	Reliance on neither habitat or prey[45]	1	Medium	Albacore employ a mixed-feeding strategy that includes specialization on anchovy, variable predation on localized prey such as hake, saury, euphausiids, or decapods, and generalized (but rare) predation on over 50 additional species.
		Average	1.75		
Distribution	Larval duration	2-8 weeks[113, 19, 114]	2	Low	No direct evidence of length of larval period is available but it is probably short since estimated size by age-1 is 45-64 cm (Wells et al. 2011; Chen et al. 2011) but uncertainty in these estimates is high as few one-year old fish are captured in any of the intensive fisheries for albacore.
	Adult/juvenile range	>1000 km[22, 87, 20]	1	High	Majority of migrating animals are believed to be juveniles. "Juvenile albacore migrate northward up the west coast of North America, averaging at least six nautical miles per day" Based on tagging data, appear to be two groups of juveniles in the WPO and EPO respectively. Some juveniles perform trans-Pacific migrations, with east to west movements more frequent than west to east trans-Pacific migrations. Migration of adults is less clear as tagging returns for adults were lower than expected. Adults move to tropical and subtropical latitudes between Hawaii and Asia.
	Physiological tolerance	>20° latitude[22, 87, 20]	1	High	Majority of migrating animals are believed to be juveniles. "Juvenile albacore migrate northward up the west coast of North America, averaging at least six nautical miles per day" Based on tagging data, appear to be two groups of juveniles in the WPO and EPO respectively. Some juveniles perform trans-Pacific migrations, with east to west movements more frequent than west

					to east trans-Pacific migrations. Migration of adults is less clear as tagging returns for adults were lower than expected. Adults move to tropical and subtropical latitudes between Hawaii and Asia.
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[22, 87, 20]	1	High	Wide distribution north and south. Available area for range expansion
		Average	1.25		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[18, 88, 112]	3	High	Evidence of seasonality and spatial variation in seasonality. Do not spawn in temperate areas
	Settlement/metamorphosis cue	No apparent correlation to environmental variable	1	Low	Albacore do not go through a true metamorphosis during their ontogeny
	Life-cycle events	Wide duration; 2-4 months[22, 87, 20]	2	Medium	Seasonal migration, seasonal spawning
	Migration	Migration is common for some of the population[22, 87, 20]	2	Medium	Juvenile albacore undergo extensive seasonal migrations. Evidence is less clear concerning movements of adult albacore. Adult widely distributed in tropical/subtropical waters from in EPO, CPO, and WPO.
		Average	2		
Total Risk Ranking			5		

EPO	Eastern Pacific Ocean - waters east of 150 W longitude
CPO	Central Pacific Ocean - waters west of 150 W longitude and east of 170 E longitude
WPO	Western Pacific Ocean - waters west of 170 E longitude.

Group: Pelagics Species: Pacific hake (*Merluccius productus*)

Species	*Merluccius productus*	Common Name: Pacific hake		Trophic level	4.4 s.e. 0.8
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[76]	1	High	80,000 - 500,000
	Recruitment	Highly episodic recruitment events[7]	3	High	Recruitment to the *Merluccius productus* population is extremely variable, evidenced by strong year classes appearing in the stock and dominating catches for 3-4 years.
	Maturity	2-10 years[10]	2	High	Mature between 3-4 years
	Generalist vs. specialist	Reliance on either habitat or prey[102]	2	High	Generalist predator, specific spawning sites
		Average	2		
Distribution	Larval duration	>2 months[102]	1	High	128 days= 18 weeks
	Adult/juvenile range	>1000 km[58]	1	High	"Although not all swimming by adults results in progress toward the spawning area, we estimate that the distance traveled is 1,100 km"
	Physiological tolerance	>20° latitude[58]	1	High	Latitudinal range:25° to 55° north
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[58]	1	High	Populations north and south, though nearing northern distribution
		Average	1		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[7]	3	Medium	Spawn January, February
	Settlement/metamorphosis cue	Strong correlation to environmental variable[58]	3	Medium	On average, three times as many recruits survive from warm years than from cold years
	Life-cycle events	Wide duration; 2-4 months[58]	2	High	
	Migration	Migration is common for the whole population[58]	3	Medium	
		Average	2.75		
Total Risk Ranking			5.75		

Group: Pelagics Species: Pacific herring (*Clupea pallasii pallasii*)

Species	*Clupea pallasii pallasii*	Common Name: Pacific herring		Trophic level	3.2 s.e. 0.4
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[54]	1	High	Fecundity in excess of 134,000 eggs
	Recruitment	Highly episodic recruitment events[109]	3	High	Annual spawning with high variability
	Maturity	≤2 years [54]	1	High	
	Generalist vs. specialist	Reliance on either habitat or prey[60]	2	High	Generalist- large range (inshore and offshore), and eats variety of small planktonic prey
		Average	1.75		
Distribution	Larval duration	<2 weeks or no larval stage [60]	3	High	
	Adult/juvenile range	10-1000 km[60]	2	High	On the west coast of Vancouver Island, BC, a tagged herring moved 150 km in 6 days
	Physiological tolerance	>20° latitude[54]	1	High	California to Alaska
	Spatial availability of habitat	No unoccupied habitat; 0-2° latitude or longitude[54]	3	High	Populations both north and south of WCVI
		Average	2.25		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[54]	3	High	Latitudinal cline in spawning - timed with "local spring"/ plankton blooms
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[60]	1	Low	
	Life-cycle events	Brief duration; <2 months[60]	3	High	Timing of life cycle events changes with latitude
	Migration	Migration is common for the whole population[109]	3	Medium	
		Average	2.5		
Total Risk Ranking			6.5		

Group: Pelagics Species: Pacific sardine (*Sardinops caerulea*)

Species	*Sardinops caerulea*	Common Name: Pacific sardine		Trophic level	2.4 s.e. 0.1
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[75]	1	High	Mature females (from 158-270 mm standard length) have multiple spawn batches in a season, each batch ranging from 10,000 to 90,000 eggs per female and 3-6 batches are common within a season (~ 1-2 weeks apart).
	Recruitment	Consistent recruitment events every 1-2 years[55]	1	High	Although adult spawning is annual, there is a high degree of interannual variability in recruitment success by year class of progeny; and sequences of poor recruitment years are linked to notable population declines and possible collapses.
	Maturity	≤2 years[13]	1	High	On average (across years) age at 50% mature ≤2 years. There is considerable inter-annual variability in both length and age based sardine maturity schedules (even within a region). For example, Macewicz et al (1996) reports that for 1994, the average female length at 50% maturity was 158.6 mm standard length, which can be fish ranging from 1-3 years (Butler et al 1996).
	Generalist vs. specialist	Reliance on neither habitat or prey[36]	1	High	Opportunistic (generalist) with habitat (dependent on sea temperature, salinity, chlorophyll etc) and opportunistic with diet (omnivorous plankton feeder)
		Average	1		
Distribution	Larval duration	<2 weeks or no larval stage[71]	3	High	213 hours at 13°C and 67 hours at 21°C
	Adult/juvenile range	10-1000 km[83]	2	High	A seasonally migratory species, with larger and stronger fish traveling furthest.
	Physiological tolerance	>20° latitude[36]	1	High	There is evidence that the California Current sardine population found near the Mexican-US border and northward) has different physiological tolerances (temperature and salinity etc) to sardines found near Ensenada in summer months and southward of Ensenada on a more general basis.
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[36]	1	High	During cool years or regimes with low population abundance, all or most of population reside in warmer southern waters. In recent years they have been seasonally predictable and numerous in Northern waters.
		Average	1.75		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[83]	2	Medium	The onset of spawning is based on the quality of forage habitat and other conditions governing when fish have enough energy reserves for gonads to mature. The extent and quality of the forage habitat in addition to spawning and rearing habitat is affected by environmental cues (temperatures, nutrient rich currents), especially because sardines are multi batch batches over a relative wide season of at least 2-4 months.

	Settlement/metamorphosis cue	Weak correlation to environmental variable[71]	2	Medium	Hatching time is mainly temperature dependent but eggs can survive a moderate range in temperature and time, but variability in depth and other ocean conditions may also affect hatching time and egg survival.
	Life-cycle events	Wide duration; 2-4 months[83]	2	High	A relatively wide spawning season benefits survival probability of early life stages since ocean transport of eggs, larvae and juvenile of sardines affects mortality and quality of rearing habitat.
	Migration	Migration is common for some of the population[36]	2	High	The extent and during of annual migrations from California into Washington and BC waters varies considerably between years. Not all the population migrates northward, sardines comprised mostly of part of the larger and older components of the population migrate earliest and furthest during a season. Therefore in addition to environmental conditions, stock composition also drives migration trends.
		Average	2		
Total Risk Ranking			4.75		

Group: Rockfish Species: Bocaccio (*Sebastes paucipinis*)

Species	*Sebastes paucipinis*	Common Name: Bocaccio		Trophic level	3.5 s.e. 0.46
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[74]	1	High	20,000-2,298,000
	Recruitment	Highly episodic recruitment events[72]	3	Low	
	Maturity	2-10 years[74]	2	High	
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Rocky outcrops
		Average	2		
Distribution	Larval duration	>2 months[74]	1	High	3.5 months- 5.5 months
	Adult/juvenile range	10-1000 km[74]	2	High	Tagged fish recaptured as much as 150km away
	Physiological tolerance	>20° latitude[74]	1	High	Southern Alaska to Northern Mexico- historical population centred around Oregon, BC currently area with highest numbers
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Available habitat north and south BUT BC is currently largest population
		Average	1.25		
Phenology	Spawning cue	No apparent correlation of spawning to environmental variable[74]	1	High	Longest spawning rockfish- nearly every month of year
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	High	Settle in 3.5 months- 5.5 months
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Spawning year round- 3.5-5.5 months as larvae
	Migration	Migration is common for some of the population[74]	2	High	Juveniles recruit to shallow, migrate to deeper waters as adults
		Average	1.25		
Total Risk Ranking			4.5		

Group: Rockfish Species: Canary rockfish (*Sebastes pinniger*)

Species	*Sebastes pinniger*	Common Name: Canary rockfish		Trophic level	3.8 s.e, 0.61
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[88]	1	High	85000-329000 eggs
	Recruitment	Highly episodic recruitment events[72]	3	High	
	Maturity	>10 years[100]	3	High	WCVI population grows quicker than other populations and may mature in 9 years
	Generalist vs. specialist	Reliance on neither habitat or prey[74]	1	High	Habitat specialization between adults and juveniles
		Average	2		
Distribution	Larval duration	>2 months[74]	1	High	
	Adult/juvenile range	10-740 km[74]	2	High	
	Physiological tolerance	>20° latitude[74]	1	High	Coastal from Northern BC/Southern Alaska to Northern Mexico
	Spatial availability of habitat	Limited unoccupied habitat; 2-6° latitude or longitude[74]	2	High	Northern extent of range S Alaska.
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[74]	3	Medium	Adults begin to spawn in February (WCVI population)
	Settlement/metamorphosis cue	Weak correlation to environmental variable[74]	2	Medium	Larvae and juveniles spend 3-4 months in upper 100m, before moving as adults to deeper water
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Long developmental period
	Migration	Migration is common for some of the population[74]	2	High	Habitat specialization according to life stage. Larva/juveniles in shallow water, Adults in deeper water
		Average	2		
Total Risk Ranking			5.5		

Group: Rockfish Species: Darkblotched rockfish (*Sebastes crameri*)

Species	*Sebastes crameri*	Common Name: Darkblotched rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[74]	1	High	20,000-610,000
	Recruitment	Occasional and variable recruitment period[72]	2	Low	
	Maturity	2-10 years[74]	2	High	5 years (30cm in Oregon) 37cm in BC
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Mud habitats near cobble/boulders
		Average	1.75		
Distribution	Larval duration	>2 months[74]	1	High	Genetic studies show it to be closely related to yellowmouth rockfish (assumed similar larval duration)
	Adult/juvenile range	<10 km[74]	3	High	Similar to other rockfish
	Physiological tolerance	>20° latitude[74]	1	High	Northern Alaska to Southern California- Peak abundance in BC
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Populations well north and south, though highest in BC
		Average	1.5		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[74]	2	Medium	Mate: August-December Fertilization: October-March Larvae released November-April
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	Medium	Similar to other rockfish
	Life-cycle events	Wide duration; 2-4 months[74]	2	High	
	Migration	Migration is common for some of the population[74]	2	High	Move into deeper waters as they get older
		Average	1.75		
Total Risk Ranking			5		

Group: Rockfish Species: Longspine thornyhead (*Sebastoiobus altivelis*)

Species	*Sebastolobus altivelis*	Common Name: Longspine thornyhead		Trophic level	3.4 s.e. 0.5
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[71]	1	High	
	Recruitment	Highly episodic recruitment events[72]	3	Low	
	Maturity	2-10 years[47]	2	Medium	Age determination is difficult - assumption made based on other rockfish
	Generalist vs. specialist	Reliance on either habitat or prey[47]	2	High	Generalist predator- limited habitat
		Average	2		
Distribution	Larval duration	>2 months[92]	1	High	20 months as larvae
	Adult/juvenile range	<10 km[47]	3	High	Juveniles (50 mm in length) settle directly into adult territory between 600 and 1,200 m, where they reportedly remain
	Physiological tolerance	>20° latitude[92]	1	High	Baja to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[92]	1	High	Large populations north and south of WCVI
		Average	1.5		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[92]	2	Medium	4-5 months of spawning centred around April with peak in February/March. No evidence of multiple spawning
	Settlement/metamorphosis cue	Weak correlation to environmental variable[92]	2	Medium	Large variation in spawning and long development
	Life-cycle events	Continuous duration; >4 months[92]	1	High	Long duration spawning, and long duration development
	Migration	No migration[47]	1	High	juveniles (50 mm in length) settle directly into adult territory between 600 and 1,200 m, where they reportedly remain
		Average	1.5		
Total Risk Ranking			5		

Group: Rockfish Species: Pacific ocean perch (*Sebastes alutus*)

Species	*Sebastes alutus*	Common Name: Pacific ocean perch		Trophic level	3.5 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[73]	1	High	168 000 eggs
	Recruitment	Highly episodic recruitment events[6]	3	Medium	The species is characterized by highly variable levels of recruitment
	Maturity	2-10 years[72]	2	High	7-10 years
	Generalist vs. specialist	Reliance on either habitat or prey[72]	2	Medium	Generalist predator, specialized habitat
		Average	2		
Distribution	Larval duration	>2 months[118]	1	High	3-6 months as larvae
	Adult/juvenile range	10-1000 km[118]	2	Medium	Genetically distinct local populations
	Physiological tolerance	10-20° latitude[53]	2	Medium	California around the Pacific rim to northern Honshu Is., Japan, including the Bering Sea
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[53]	1	High	Significant populations north and south of WCVI
		Average	1.5		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[118]	2	Medium	Multiple spawning groups at different times, though individuals only spawn once (different local populations spawn separately) Suggest lack of environmental cue
	Settlement/metamorphosis cue	Weak correlation to environmental variable[118]	2	Medium	Long development and multiple spawning groups suggest lack of environmental cues
	Life-cycle events	Continuous duration; >4 months[118]	1	Medium	Long development, and long spawning season
	Migration	Migration is common for some of the population[6]	2	High	Pacific ocean perch undergo a seasonal bathymetric migration in Goose Island Gully, spending the winter and spawning in deeper water (> 275m), then moving to shallower water(180-220 m) in summer
		Average	1.75		
Total Risk Ranking			5.25		

Group: Rockfish Species: Redbanded rockfish (*Sebastes babcocki*)

Species	*Sebastes babcocki*	Common Name: Redbanded rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[71]	1	High	1 279 813
	Recruitment	Highly episodic recruitment events[72]	3	Medium	See other rockfish
	Maturity	>10 years[117]	3	High	In BC mature in 19 years
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Hard bottom
		Average	2.25		
Distribution	Larval duration	>2 months[74]	1	Medium	See other rockfish
	Adult/juvenile range	<10 km[74]	3	Medium	See other rockfish
	Physiological tolerance	>20° latitude[74]	1	High	Bering Sea to San Diego
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Most abundant South Alaska-Oregon
		Average	1.5		
Phenology	Spawning cue	No apparent correlation of spawning to environmental variable[74]	1	Medium	Larval release: March-September (no differences according to latitude)
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	Medium	No difference according to latitude
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Spawning March-September (7 months)
	Migration	Migration is common for some of the population[74]	2	Medium	See other rockfish
		Average	1.25		
Total Risk Ranking			5		

Group: Rockfish Species: Redstripe rockfish (*Sebastes proriger*)

Species	*Sebastes proriger*	Common Name: Redstripe rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[23]	1	Medium	All other rockfish species produce several hundred thousand eggs per spawning event
	Recruitment	Highly episodic recruitment events[24]	3	High	"Limited data gathered 1990-1992 suggest that 1982 was the last year that a significant recruitment event occurred"
	Maturity	2-10 years[74]	2	High	Age 6 - 7
	Generalist vs. specialist	Reliance on either habitat or prey[84]	2	High	*S. proriger* requires hard bottom habitat. Data deficient for prey
		Average	2		
Distribution	Larval duration	>2 months[66]	1	High	
	Adult/juvenile range	10-1000 km	2	Medium	Many rockfish rear at shallow depths before migrating to deeper waters where they have a very high site fidelity
	Physiological tolerance	>20° latitude[24]	1	High	southern California to Bering Sea
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[24]	1	High	Significant habitat north and south
		Average	1.25		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[34]	3	High	Seasonal spawning
	Settlement/metamorphosis cue	Strong correlation to environmental variable[85]	3	High	Seasonal and occurs in kelp beds
	Life-cycle events	Wide duration; 2-4 months[34]	2	High	Spawning occurs over several spring months
	Migration	Migration is common for some of the population[71]	2	Medium	Juvenile Rockfish recruit to shallower depths than those occupied by conspecific adults. However, once recruit to a site they show high site fidelity
		Average	2.5		
Total Risk Ranking			5.75		

Group: Rockfish Species: Rougheye rockfish (*Sebastes aleutianus*)

Species	*Sebastes aleutianus*	Common Name: Rougheye rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[71]	1	High	1,279,813 eggs
	Recruitment	Highly episodic recruitment events[72]	3	Low	Yearly spawning though some years weaker recruitment
	Maturity	>10 years[74]	3	High	50% mature in 20 years
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Steeply sloped boulder fields
		Average	2.25		
Distribution	Larval duration	>2 months[72]	1	High	Most species mature 3-5months
	Adult/juvenile range	<10 km[72]	3	High	High site fidelity
	Physiological tolerance	>20° latitude[74]	1	High	Japan-Bering Sea to San Diego
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Most abundant from Bering sea to Oregon
		Average	1.5		
Phenology	Spawning cue	No apparent correlation of spawning to environmental variable[74]	1	Medium	February - June (and some in October-January)
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[72]	1	Medium	
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Nearly year round spawning
	Migration	Migration is common for some of the population[72]	2	High	Juveniles move into deeper waters as they mature
		Average	1.25		
Total Risk Ranking			5		

Group: Rockfish Species: Sharpchin rockfish (*Sebastes zacentrus*)

Species	*Sebastes zacentrus*	Common Name: Sharpchin rockfish		Trophic level	3.6 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	100-20,000 eggs per year[72]	2	High	See other rockfish
	Recruitment	Highly episodic recruitment events[72]	3	Medium	
	Maturity	2-10 years[74]	2	High	Washington- 50% females mature in 6 years and 50% males mature in 7 years Alaska- 50% maturity (M/F) in 10 years British Columbia- 50% mature (M/F) <10years
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Juveniles shallower than Adults- usually over cobble mud or boulder mud Generalist predators including krill, shrimp, amphipods copepods and small fish
		Average	2.25		
Distribution	Larval duration	>2 months[72]	1	Medium	See other rockfish
	Adult/juvenile range	<10 km[72]	3	Medium	
	Physiological tolerance	>20° latitude[74]	1	High	Western Aleutian islands to San Diego
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Populations well north and south
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[74]	3	Medium	Spawn release in July
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	Medium	No change in spawning with latitude
	Life-cycle events	Brief duration; <2 months[74]	3	Medium	
	Migration	Migration is common for some of the population[72]	2	High	Juveniles move to deeper water as they mature
		Average	2.25		
Total Risk Ranking			6		

Group: Rockfish Species: Shortraker rockfish (*Sebastes borealis*)

Species	*Sebastes borealis*	Common Name: Shortraker rockfish		Trophic level	3.9 s.e. 0.5
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[71]	1	High	See similar rockfish
	Recruitment	Highly episodic recruitment events[72]	3	Low	See similar rockfish
	Maturity	>10 years[74]	3	High	Mature 9-12 years
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Rocky habitats- varied diet
		Average	2.25		
Distribution	Larval duration	>2 months[72]	1	High	See other rockfish
	Adult/juvenile range	<10 km[72]	3	High	See other rockfish
	Physiological tolerance	>20° latitude[74]	1	High	Japan-Aleutian Islands-Northern Alaska To Southern California
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Most common: Alaska to British Columbia
		Average	1.5		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[74]	2	Medium	March-July (possibly later into early fall)
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	Medium	
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Spring to Fall
	Migration	Migration is common for some of the population[74]	2	High	Young live in shallower water than adults
		Average	1.5		
Total Risk Ranking			5.25		

Group: Rockfish Species: Shortspine thornyhead (*Sebastolobus alascanus*)

Species	*Sebastolobus alascanus*	Common Name: Shortspine thorny head rockfish		Trophic level	3.6 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[71]	1	High	235 000 eggs
	Recruitment	Highly episodic recruitment events[34]	3	Medium	
	Maturity	>10 years[74]	3	High	50% mature in 12 years
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Rocky substrate
		Average	2.25		
Distribution	Larval duration	>2 months[74]	1	High	14-15 Months
	Adult/juvenile range	<10 km[74]	3	High	Remain motionless on seafloor for long periods of time
	Physiological tolerance	>20° latitude[74]	1	High	Japan-Bering Sea- to Baja Mexico
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Japan-Bering Sea- to Baja Mexico
		Average	1.5		
Phenology	Spawning cue	No apparent correlation of spawning to environmental variable[74]	1	Medium	January-May
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	Medium	Longest larval period of rockfish 14-15 months
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Longest larval period of rockfish 14-15 months
	Migration	Migration is common for some of the population[74]	2	High	Migrate to deeper waters as they mature
		Average	1.25		
Total Risk Ranking			5		

Group: Rockfish Species: Silvergrey rockfish (*Sebastes brevispinis*)

Species	*Sebastes brevispinis*	Common Name: Silvergrey rockfish		Trophic level	3.8 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[104]	1	High	181,000 - 1.9 Million
	Recruitment	Highly episodic recruitment events[72]	3	High	
	Maturity	>10 years[104]	3	High	10 years-16 years
	Generalist vs. specialist	Reliance on either habitat or prey[104]	2	High	Rocky habitats near continental slope
		Average	2.25		
Distribution	Larval duration	>2 months[66]	1	Low	Long larval duration common in rockfish
	Adult/juvenile range	10-1000 km[104]	2	High	Seasonal movements according to water temperature
	Physiological tolerance	>20° latitude[104]	1	High	Northern Gulf of Alaska- Baja California
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[104]	1	High	
		Average	1.25		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[104]	2	High	April-June
	Settlement/metamorphosis cue	Weak correlation to environmental variable[104]	2	High	
	Life-cycle events	Wide duration; 2-4 months[104]	2	High	
	Migration	Migration is common for some of the population[104]	2	High	Seasonal movements
		Average	2		
Total Risk Ranking			5.5		

Group: Rockfish Species: Splitnose rockfish (*Sebastes diploproa*)

Species	*Sebastes diploproa*	Common Name: Splitnose rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[74]	1	Medium	14,000-255,000 eggs
	Recruitment	Highly episodic recruitment events[72]	3	Medium	
	Maturity	>10 years[74]	3	High	Mature 9+ years
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	Medium	Low-relief mud fields
		Average	2.25		
Distribution	Larval duration	>2 months[66]	1	Low	Similar species larval for 3-5months
	Adult/juvenile range	<10 km[74]	3	High	While usually sedentary, schools can form and move up to 100m
	Physiological tolerance	>20° latitude[43]	1	High	Alaska to Baja California
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[43]	1	Medium	Found in their highest densities off northern California
		Average	1.5		
Phenology	Spawning cue	No apparent correlation of spawning to environmental variable[74]	1	High	Year round reproduction
	Settlement/metamorphosis cue	No apparent correlation to environmental variable[74]	1	High	Year round reproduction
	Life-cycle events	Continuous duration; >4 months[74]	1	High	Year round reproduction
	Migration	Migration is common for some of the population[74]	2	Medium	Migration from shallow to deep waters with transition from juvenile to adult is common for all rockfish
		Average	1.25		
Total Risk Ranking			5		

Group: Rockfish Species: Vermilion rockfish (*Sebastes miniatus*)

Species	*Sebastes miniatus*	Common Name: Vermilion rockfish		Trophic level	3.8 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[48]	1	High	151 000 to 5.6 million
	Recruitment	Highly episodic recruitment events[85]	3	Medium	High variation in larval mortality may contribute to extremely variable recruitment
	Maturity	2-10 years[34]	2	High	
	Generalist vs. specialist	Reliance on either habitat or prey[95]	2	High	High site fidelity, feed on several species on small fish and possibly crustaceans
		Average	2		
Distribution	Larval duration	>2 months[66]	1	Medium	Larval dispersal is considered to be exceedingly limited
	Adult/juvenile range	<10 km[52]	3	High	High site fidelity
	Physiological tolerance	>20° latitude[4]	1	High	Mexico to Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[4]	1	High	Large neighboring populations to south to Mexico and north to Alaska
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[34]	3	Medium	
	Settlement/metamorphosis cue	Strong correlation to environmental variable[85]	3	Medium	Seasonal and occurs in kelp beds
	Life-cycle events	Wide duration; 2-4 months[34]	2	High	Spawning occurs over 4 to 5 months
	Migration	Migration is common for some of the population[71]	2	High	Juvenile Rockfish recruit to shallower depths than those occupied by conspecific adults
		Average	2.5		
Total Risk Ranking			6		

Group: Rockfish Species: Widow rockfish (*Sebastes entomelas*)

Species	*Sebastes entomelas*	Common Name: Widow rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[48]	1	High	134000 to 948000
	Recruitment	Highly episodic recruitment events[85]	3	High	High variation in larval mortality may contribute to extremely variable recruitment
	Maturity	2-10 years[34]	2	High	
	Generalist vs. specialist	Reliance on either habitat or prey[2]	2	High	Associated with rocky reefs. Four major food preferences (salps, fish, shrimp, euphasids) however there is strong seasonal and diurnal reliance on prey
		Average	2		
Distribution	Larval duration	>2 months[66]	1	Medium	Suspected that larval duration is around 100 days
	Adult/juvenile range	<10 km[96]	3	High	
	Physiological tolerance	>20° latitude[25]	1	High	Found from southern California to Gulf of Alaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[25]	1	High	Significant habitat north and south
		Average	1.5		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[34]	3	High	Strong seasonal patterns in spawning
	Settlement/metamorphosis cue	Strong correlation to environmental variable[85]	3	High	Seasonal and occurs in kelp beds
	Life-cycle events	Wide duration; 2-4 months[34]	2	High	Spawning occurs over 4 to 5 months
	Migration	Migration is common for some of the population[71]	2	High	Juvenile rockfish recruit to shallower depths than those occupied by conspecific adults
		Average	2.5		
Total Risk Ranking			6		

Group: Rockfish Species: Yellowmouth rockfish (*Sebastes reedi*)

Species	*Sebastes reedi*	Common Name: Yellowmouth rockfish		Trophic level	3.7 s.e. 0.6
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[120]	1	Medium	"Fecundity is unknown but ranges from approximately 1700 to 412000 eggs in other rockfish"
	Recruitment	Highly episodic recruitment events[26]	3	High	"Limited age data gathered between 1990 and 1992 suggest that 1982 was the last year that a significant recruitment event occurred in the yellowmouth rockfish stocks in BC"
	Maturity	>10 years[101]	3	High	"Individuals mature at approximately 10 years of age"
	Generalist vs. specialist	Reliance on either habitat or prey[40]	2	High	"As rockfish mature they switch to a variety of fish and crustacean prey, including Herring, Sandlance, crabs, shrimps, as well as euphausiids"
		Average	2.25		
Distribution	Larval duration	>2 months[28]	1	High	"release of larvae that spend months as free-swimming pelagic larvae before settling to the bottom as juveniles"
	Adult/juvenile range	<10 km[101]	3	High	"Adult yellowmouth rockfish demonstrate site fidelity and homing behaviour and may persist in the same site-specific aggregations for years"
	Physiological tolerance	10-20° latitude[101]	2	High	"the range of yellowmouth rockfish extends from the northern Gulf of Alaska to northern California"
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[101]	1	Medium	"the range of yellowmouth rockfish extends from the northern Gulf of Alaska to northern California"
		Average	1.75		
Phenology	Spawning cue	Strong correlation of spawning to environmental variable[28]	3	High	"In BC waters, larval release occurs from February to June"
	Settlement/metamorphosis cue	Weak correlation to environmental variable[101]	2	Medium	Weak indications of recruitment seasonality
	Life-cycle events	Wide duration; 2-4 months[28]	2	High	"In BC waters, larval release occurs from February to June"
	Migration	Migration is common for some of the population[26]	2	High	Relatively high site fidelity
		Average	2.25		
Total Risk Ranking			6.25		

Group: Rockfish Species: Yellowtail rockfish (*Sebastes flavidus*)

Species	*Sebastes flavidus*	Common Name: Yellowtail rockfish		Trophic level	4.1 s.e. 0.7
Attribute	Criteria	Risk Ranking		Certainty	Comments
		Category	Score		
Abundance	Fecundity	>20,000 eggs per year[35]	1	High	56,000 to 1,992,700 eggs for age-6-48
	Recruitment	Highly episodic recruitment events[35]	3	High	
	Maturity	2-10 years[35]	2	High	Recruit to the fishery at age 5
	Generalist vs. specialist	Reliance on either habitat or prey[74]	2	High	Inhabit rocky reefs and have high site fidelity. Opportunistic feeders
		Average	2		
Distribution	Larval duration	>2 months[85]	1	High	3.5 months
	Adult/juvenile range	10-1000 km[85]	2	High	Tagging studies have shown considerable movement. 400km and on adult moved 1400km, though most yellowtail inhabit the same general area for extensive periods and have strong homing ability.
	Physiological tolerance	>20° latitude[23]	1	High	Baja California to Unalaska
	Spatial availability of habitat	Substantial unoccupied habitat >6°latitude or longitude[74]	1	High	Population continuous north and south of WCVI
		Average	1.25		
Phenology	Spawning cue	Weak correlation of spawning to environmental variable[35]	2	Medium	Fall spawning, with larvae being released between January and April
	Settlement/metamorphosis cue	Weak correlation to environmental variable[23]	2	Medium	Seasonal settlement (no obvious) environmental cue-developmental rate temp dependant
	Life-cycle events	Wide duration; 2-4 months[74]	2	Medium	Seasonal spawning with longer larval development.
	Migration	Migration is common for some of the population[74]	2	High	Migrate to deeper waters as they mature
		Average	2		
Total Risk Ranking			5.25		

APPENDIX 7.2. Expert Survey: Species Sensitivity to Climate Change in WCVI

In February of 2013, attendees of the annual State of the Pacific Ocean Workshop (Irvine and Crawford 2013) were invited to provide assessments of WCVI species sensitivity to climate change given a 50 year time frame (Questionnaire on p. 75). The purpose of this exercise was to solicit expert opinion of the climate change risk to select marine species. Those in attendance were provided with a paper questionnaire inviting them to score 14 species on their sensitivity to climate change (i.e. not sensitive, moderately sensitive or highly sensitive). These species were drawn from larger species groups used for the framework assessment. No elasmobranch species were included in the survey.
Respondents were asked to score the direction of the species' change in abundance (negative, positive, or no change) and their confidence in each of their species assessments (low, medium or high confidence). They were asked about their area of expertise, time spent in their field and any additional comments on their assessment. Subjects were informed that their identity would not be collected. An online version of the questionnaire was made available and advertised to Pacific Region DFO scientists and members of The University of British Columbia Fisheries Centre. Three of the paper questionnaires were completed and returned. An additional four questionnaires were completed online. See Table 2 for raw questionnaire data.

Subjects completing questionnaires were all marine scientists with varying fields of expertise (plankton, invertebrates, groundfish, rockfish, pelagics, salmon, genetics, ecology). All but one had spent more than 5 years in their respective field.

Appendix Table 1. Species assessed by local experts and the number of assessments obtained for each species.

Species group	Species	Number of assessments
Invertebrates	Dungeness crab	5
	Pacific oyster (native)	5
	Geoduck	5
	Shrimp (multiple species)	5
Groundfish	Arrowtooth flounder	4
	Dover sole	4
	Sablefish	5
Rockfish	Longspine thornyhead	4
	Pacific ocean perch	5
	Widow rockfish	4
Pelagics	Pacific herring	5
	Albacore tuna	6
	Pacific hake (semi-pelagic)	6
	Pacific sardine	5

INVERTEBRATES

In nearly all cases, representative invertebrates are described as being either moderately or highly sensitive to climate change and in most cases were predicted to undergo negative changes in abundance. Participants most consistently scored Pacific Oyster as 'highly sensitive' with high degree of confidence. Three assessments of Pacific oyster suggested a negative change in abundance of the species while the other two assessments suggested no change in abundance. Respondents assigned geoduck three "highly sensitive" and two "moderately sensitive" scores. In all cases, the anticipated change in abundance was negative. One score was given with a high degree of confidence, three with medium degrees of confidence and one with a low degree of confidence. Dungeness crab was assessed as moderately sensitive to climate change in 4 of 5 assessments and highly sensitive in one assessment. In all but one instance, there was an anticipated negative predicted change in abundance. Three assessments were given with either a medium or high degree of confidence and two assessments were given with low confidence. Shrimp were assessed as moderately sensitive (four scores) or not sensitive (one score). In all but one assessment there is an anticipated negative change in abundance. Only one shrimp score was given with a high degree of confidence and it should be noted that this assessment is considerably different from the others in that it assesses shrimp as not sensitive to climate change and predicts no change in abundance.

GROUNDFISH

Groundfish assessments are characterized by a low to medium degree of confidence in which scores were assigned and an inconsistency in scores between assessments. All assessments considered arrowtooth flounder as highly or moderately sensitive to climate change, however, there was not agreement on the direction of change in abundance. Three out four assessments predict a negative abundance trajectory while one predicts a positive change. Dover sole is assesses as moderately (three assessments) to highly sensitive (one assessment) to climate change. Three out of four assessments predict a negative change in abundance while the last predicts no change. Sablefish is assessed as not sensitive (two scores) to moderately sensitive (three scores) with three out of five scores predicting no change in abundance and two predicting a negative change.

ROCKFISH

All three species of rockfish (longspine, Pacific Ocean perch and widow rockfish) are consistently evaluated as moderately or highly sensitive to climate change and in most cases the anticipated change in abundance is negative. None of the species are predicted to have a positive change in abundance. Those surveyed give low and medium confidence score to their assessments.

One assessment provided comments specific to Pacific Ocean perch. The comment notes that hake live at depths that are predicted to undergo significant oxygen loss (125-300m) making them vulnerable to hypoxia. The comment states that hake may be forced either to shallower habitat or northward to Alaska's oxygen enriched waters – both are areas with different competition/predation dynamics.

PELAGICS

Pelagic species garnered the largest number of assessments (22) and those surveyed consistently expressed a medium or high level of confidence in their evaluation. None express low confidence in their assessment. In every assessment, each of the four species received a score of moderate or high for sensitivity to climate change. Pacific hake received the greatest number of "high sensitivity" scores (four), however there was no consensus on the direction of change in their species abundance. Half of hake assessments predicted an increase in abundance while the other half predicted a decline. The single hake evaluation assessed with high confidence predicts a positive population growth trajectory. Pacific sardine received three "high sensitivity" scores with three of five assessments predicting increases in abundance, one predicting a decline and one predicting no change. Pacific herring received two "high sensitivity" scores and three moderate sensitivity scores. All evaluations predicted a negative change in abundance, with four of the assessments being given with a medium level of confidence and one, a high level of confidence. Albacore tuna was deemed moderately sensitive to climate change in five of six assessments and highly sensitive in one. All but two of the evaluations predicted a positive change in abundance with the outliers predicting a negative response and no response. Half of albacore assessments were given with a medium level of confidence, two with a low level of confidence and one with a high level of confidence.

Three evaluations provided additional comments relevant to pelagic species. The first noted that high levels of uncertainty exist for species that are migratory due to a lack of information about connectivity between rearing grounds and adult forage and spawning grounds. For migratory species for which this information exists (i.e. Pacific herring) there appear to be negative physiological and ecological impacts due to higher ocean temperatures: fish are more prone to disease and their diets are significantly changed due to an absence of cold water zooplankton. They also note that juvenile survival would be expected to decline with warmer temperatures and higher energy meteorological conditions in the nearshore.

The second set of comments notes that seasonal movements of albacore tuna are affected by atmospheric forcing of oceans, particularly sea surface temperature. They note that certain temperature ranges are preferred. However, it is unknown how reproduction or recruitment are affected by atmospheric-ocean forcing or SST. Without this information it is very difficult to predict changes in albacore abundance with any confidence.

The third set of comments notes that hake live at depths that are predicted to undergo significant oxygen loss (125-300m) making them vulnerable to hypoxia. The comment states that hake may be forced either to shallower habitat or northward to Alaska's oxygen enriched waters – both are areas with different competition/predation dynamics.

QUESTIONNAIRE

Climate Change & West Coast Vancouver Island Fisheries: Assessing Risk to Non-salmon Species

DFO Science is conducting an analysis of the impacts of climate change to marine species on the west coast of Vancouver Island (WCVI). We are seeking expert input for species of high commercial importance.

Please assess of the vulnerability to climate change of each species listed below by circling the appropriate value. The time frame is 50 years hence (i.e. year 2063). Base your assessment on how you expect each species might respond to climate change related alterations in temperature, currents, pH, food webs etc. While no one is an expert on all species, we encourage you to complete the form for as many species groups as you are comfortable with, adjusting your confidence rating as appropriate. This questionnaire is anonymous; however we would like some basic information about you, which can be provided on the reverse.

Comments or explanations of your assessments can also be left on the reverse.

WCVI Species Group	Species of highest commercial importance	Sensitivity to climate change 1 = not sensitive 2 = moderately sensitive 3 = highly sensitive			Change in the abundance by year 2063 N = negative change NC = no change P = positive change			Confidence in your assessment L = low confidence M = medium confidence H = high confidence		
Invertebrates	Dungeness crab	1	2	3	N	NC	P	L	M	H
	Pacific (native) oyster	1	2	3	N	NC	P	L	M	H
	Geoduck	1	2	3	N	NC	P	L	M	H
	Shrimp (multiple species)	1	2	3	N	NC	P	L	M	H
Groundfish	Arrowtooth flounder	1	2	3	N	NC	P	L	M	H
	Dover sole	1	2	3	N	NC	P	L	M	H
	Sablefish	1	2	3	N	NC	P	L	M	H
Rockfish	Longspine thornyhead	1	2	3	N	NC	P	L	M	H
	Pacific ocean perch	1	2	3	N	NC	P	L	M	H
	Yellowtail rockfish	1	2	3	N	NC	P	L	M	H
	Widow rockfish	1	2	3	N	NC	P	L	M	H
Pelagics	Pacific herring	1	2	3	N	NC	P	L	M	H
	Albacore tuna	1	2	3	N	NC	P	L	M	H
	Pacific hake	1	2	3	N	NC	P	L	M	H
	Pacific sardine	1	2	3	N	NC	P	L	M	H

Information about you

Area of expertise: _____

Time spent in this field of research: _____

Date: _____

Please leave comments about your species assessments or this questionnaire, here.

Appendix Table 2. Expert survey responses.

RespondentID	**2528856680**	**2494253929**	**2494137899**	**2489787699**	Paper response 1	Paper response 2	Paper response 3
Responses per species:							
Dungeness crab - sensitivity to climate change	moderate	moderate	high	moderate		moderate	
Dungeness crab - anticipated change in abundance	negative	none	negative	negative		negative	
Dungeness crab - confidence in the assessment	low	low	high	medium		medium	
Pacific (native) oyster - sensitivity to climate change	high	moderate	high	high		high	
Pacific (native) oyster - anticipated change in abundance	none	none	negative	negative		negative	
Pacific (native) oyster - confidence in the assessment	low	low	high	medium		medium	
Geoduck - sensitivity to climate change	moderate	moderate	high	high		high	
Geoduck - anticipated change in abundance	negative	negative	negative	negative		negative	
Geoduck - confidence in the assessment	low	medium	high	medium		medium	
Shrimp (all species) - sensitivity to climate change	moderate	not	moderate	moderate		moderate	
Shrimp (all species) - anticipated change in abundance	negative	none	negative	negative		negative	
Shrimp (all species) - confidence in the assessment	low	high	medium	medium		medium	
Arrowtooth flounder - sensitivity to climate change	moderate	high		moderate		high	

Arrowtooth flounder - anticipated change in abundance	negative	negative		positive		negative	
Arrowtooth flounder - confidence in the assessment	low	medium		medium		low	
Dover sole - sensitivity to climate change	moderate	high		moderate		moderate	
Dover sole - anticipated change in abundance	none	negative		negative		negative	
Dover sole - confidence in the assessment	low	low		medium		low	
Sablefish - sensitivity to climate change	not	moderate	not	moderate		moderate	
Sablefish - anticipated change in abundance	none	none	none	negative		negative	
Sablefish - confidence in the assessment	low	medium	medium	medium		low	
Longspine thornyhead - sensitivity to climate change	moderate	high		moderate		moderate	
Longspine thornyhead - anticipated change in abundance	negative	negative		negative		none	
Longspine thornyhead - confidence in the assessment	low	high		medium		low	
Pacific ocean perch - sensitivity to climate change	moderate	moderate		moderate		moderate	high
Pacific ocean perch - anticipated change in abundance	negative	none		negative		none	negative
Pacific ocean perch - confidence in the assessment	low	medium		medium		low	medium
Widow rockfish - sensitivity to climate change	moderate	moderate		moderate		moderate	
Widow rockfish - anticipated change in	negative	none		negative		negative	

abundance							
Widow rockfish - confidence in the assessment	medium	medium		medium		low	
Pacific herring - sensitivity to climate change	high	moderate	moderate	high		moderate	
Pacific herring - anticipated change in abundance	negative	negative	negative	negative		negative	
Pacific herring - confidence in the assessment	medium	medium	medium	high		medium	
Albacore tuna - sensitivity to climate change	moderate	high	moderate	moderate	moderate	moderate	
Albacore tuna - anticipated change in abundance	positive	positive	positive	negative	none	positive	
Albacore tuna - confidence in the assessment	low	high	medium	medium	low	medium	
Pacific hake - sensitivity to climate change	high	high	moderate	moderate		high	high
Pacific hake - anticipated change in abundance	positive	positive	negative	negative		positive	negative
Pacific hake - confidence in the assessment	medium	high	medium	medium		medium	medium
Pacific sardine - sensitivity to climate change	high	high	moderate	moderate		high	
Pacific sardine - anticipated change in abundance	positive	positive	negative	none		positive	
Pacific sardine - confidence in the assessment	medium	high	medium	medium		medium	
Please choose areas of expertise that best describes you:							

phytoplankton		phytoplankton		Pelagics	zooplankton		
zooplankton		zooplankton					
invertebrates		invertebrates					
groundfish		groundfish					
rockfish		rockfish					
pelagics		pelagics	pelagics	pelagics			
salmon	salmon	salmon					
fish genetics		fish genetics					
ecologist	ecologist	ecologist	ecologist				
non-marine biologist							
non-biologist							
Additional information (please specify)				Mostly clupeids/pelagics ecology but have collaborated and been exposed to ecology associated with groundfish and shellfish species.	Albacore tuna	zooplankton	Ocean oxygen
Time spent in this field of research	> 5 years	> 5 years	< 5 years	> 5 years	10 years	30+	several years
Time spent in this field of research - Other (please specify)				>12 years with DFO plus 4 years university			